BBC

DOES TAKING VITAMINS WORK?

HANNAH FRY'S HIDDEN MATHS OF EVERYDAY LIFE

WHY POSITIVITY IS OVERRATED

Science Focus

ENDING THE YEAR WITH A BANG

SPECIAL ISSUE

RADICAL THEORIES YOU NEED TO KNOW

WILD IDEAS TO BLOW YOUR MIND

AGEING HAS AN OFF-SWITCH

BABIES WITHOUT PREGNANCY

PLANTS ARE CONSCIOUS

MUSHROOMS CAN SAVE THE WORLD

ROBOTS WON'T THINK LIKE US

WE'VE ALREADY FOUND LIFE ON MARS

DEATH IS REVERSIBLE

DARK MATTER IS UNDER OUR FEET

CATCH THE WINTER LIGHT
WITH NIKON

INSTANT
SAVINGS

SAVE TODAY

CAPTURE TOMORROW

Get instant discounts on selected Nikon cameras and NIKKOR lenses.
The time is now! Offer available from **15th October 2019 until 15th January 2020**.
For further information and full terms and conditions please visit **nikonpromotions.co.uk**
Available at participating retailers.

Nikon

Do I really need to wash veg if I'm cooking it anyway? →p88

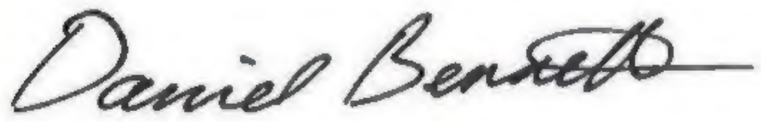
FROM THE EDITOR

The first science book I ever read blew my mind. I can't remember the name of the book, but I know who it was written by: Marcus Chown. In it he explained, in his effortless way, how the Universe began and how it might all end. To this day, the sense of wonder that Marcus's writing inspired epitomises what makes science, and writing and reading about it, so special.

So as the year comes to an end and we all start traversing the country to visit friends and relatives during the holidays, I wanted to share a little scientific wonder with you all. This special issue celebrates some of the most mind-expanding ideas in science right now. From the search for dark matter to the quest to end ageing, there's hopefully something for everyone, so steal away with this magazine to a quiet corner and dive in (p52).

And if you're feeling a little bit grumpy this Christmas, then you should head to p76. It seems like every self-help book, motivational speaker and YouTube wants to convince the world that we can achieve our dreams if we can only be a bit more positive, but it turns out they haven't got it all figured out.

Enjoy the holidays, and we'll see you in 2020!



Daniel Bennett, Editor

ON THE BBC THIS MONTH...

Island Medics
This new series follows doctors, nurses, paramedics and lifeboat crews at Gilbert Bain Hospital on the Shetland Islands, the UK's most remote hospital.
BBC iPlayer

Baby Chimp Rescue
Two biologists become surrogate parents to orphaned baby chimps. Together with primatologist Ben Garrod, they must build a permanent home for the chimpanzees.
Begins in the New Year, BBC Two

Science Stories
The series profiling lesser known stories in science. In the first episode, Naomi Alderson tells the story of how the self-taught Mary Somerville became a pioneer of popular science writing.
11, 18 and 25 December, BBC Sounds

CONTRIBUTORS

ALLA KATSNELSON
Alla is a science writer, with a PhD in mammalian development. This issue, she investigates artificial wombs, and babies without pregnancy. → p52

DEAN BURNETT
Do antidepressants actually work? Neuroscientist and author Dean explains why these drugs get such a bad press, and why we shouldn't dismiss them. → p33

AMY FLEMING
A significant number of people in vegetative states may have hidden consciousness. Freelance science writer Amy finds out about the scientists who are treating these patients. → p72

HANNAH FRY
This year's Royal Institution Christmas Lectures will delve into the maths behind everyday life. Mathematician Hannah, who is this year's host, tells us how maths is hiding in plain sight. → p66

CONTACT US

Advertising
sam.jones@immediate.co.uk
0117 300 8145
Letters for publication
reply@sciencefocus.com
Editorial enquiries
editorialenquiries@sciencefocus.com
0117 300 8755
Subscriptions
bbcsciencefocus@buysubscriptions.com
03330 162 113*
Other contacts
sciencefocus.com/contact

COVER: SAM FALCONER

*Calls from landlines will cost up to 9p per minute. Calls from mobile phones will cost between 3p and 55p per minute but are included in free call packages. Lines are open 8am-6pm weekdays and 9am-1pm Saturday for orders only. If calling from overseas, please call +44 1604 973 721. *BBC Science Focus* (ISSN 0966-4270) (USPS 015-160) is published 14 times a year (monthly with a Summer issue in July and a Christmas issue in December) by Immediate Media Company, Bristol, Eagle House, Colston Avenue, Bristol, BS1 4ST. Distributed in the US by Circulation Specialists, LLC, 2 Corporate Drive, Suite 945, Shelton, CT 06484-6238. Periodicals postage paid at Shelton, CT and additional mailing offices. POSTMASTER: Send address changes to *BBC Science Focus*, PO Box 37495, Boone, IA 50037-0495.

CONTENTS

REGULARS

13
DISCOVERIES

Surgeons have put a patient into suspended animation by injecting cold saline into their blood.

28
REALITY CHECK

For a long time, badger culls have been carried out to prevent bovine TB. But do they work?

44
HOW TO GROW FOOD IN SPACE

Scientists in Antarctica are trialling techniques for growing food on the Moon and Mars. And so far, they have a pretty successful harvest...

FEATURES

52
WILD IDEAS TO BLOW YOUR MIND

72
IS THERE ANYBODY IN THERE?

66
INTERVIEW: DR HANNAH FRY, MATHEMATICIAN

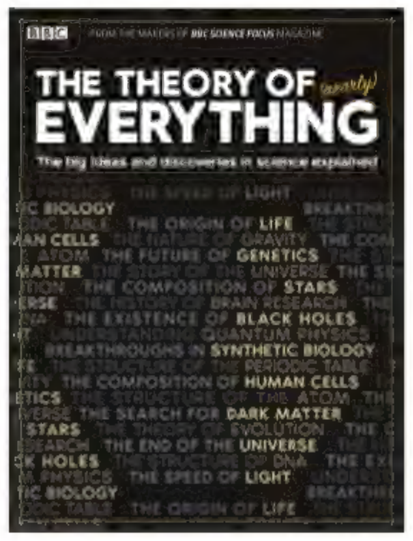
"MATHS TEACHING IN SCHOOLS IS LIKE BEING TAUGHT MUSIC BY ONLY EVER PLAYING SCALES AND NEVER LISTENING TO ANY OTHER MUSIC"

WANT MORE?

Don't forget that *BBC Science Focus* is also available on all major digital platforms. We have versions for Android, Kindle Fire and Kindle e-reader, as well as an iOS app for the iPad and iPhone.

Can't wait until next month to get your fix of science and tech? Our website is packed with news, articles and Q&As to keep your brain satisfied.
sciencefocus.com

SPECIAL ISSUE



THE THEORY OF (NEARLY) EVERYTHING
In this special edition, brought to you by the team at *BBC Science Focus*, we take a tour of the most incredible phenomena in the Universe, from the Big Bang to the Big Bounce – and everything in between.
buysubscriptions.com/focuscollection

EYE OPENER

Flaming forest

CALIFORNIA, USA

Firefighters battle to control forest fire Maria, which raged in California's Ventura County for six days in October and early November. Strong winds meant Maria grew quickly to consume over 7,500 hectares (16km^2) of land before being extinguished with water dropped by three DC-10 aeroplanes.

Sadly, local firefighters have had a lot of problems with fires this year: at the time of writing the 2019 season has seen 6,402 fires destroy over 100,000 hectares (250,000 acres) of land and over 500 buildings. While wildfires are not uncommon in California, the intensity of Maria's blaze is cause for concern.

In 2018, a team of scientists from the University of California discovered that increasing droughts in the area, thought to be caused by global climate change, had led to high tree mortality. They predicted the dead trees would become kindling for huge wildfires beyond the state's current model.

SHUTTERSTOCK

VISIT US FOR MORE AMAZING IMAGES:

SCIENCEFOCUS

BBCSCIENCEFOCUS

EYE OPENER

Volatile volcano

ANTOFAGASTA, CHILE

South America is home to some of the world's least-studied volcanoes, something that Dr Yves Moussallam, a post-doctoral researcher at the University of Cambridge, and his team hope to change. Their work took them to this active volcano, called Lastarria.

Covering the top of Lastarria is yellow sulphur, deposited centuries ago. The researchers wear gas masks when taking measurements to protect themselves from compounds emitted from the volcano, such as sulphur dioxide, carbon monoxide and methane.

"Soon we'll have a global map of all the volcanic gases being added to our atmosphere," says Moussallam. This is useful, as it means we can better understand how volcanic gases affect the climate. For example, carbon dioxide has a cooling effect on local climate, whereas acidic gases can affect the chemistry of rainfall leading to acid rain.

YVES MOUSSALLAM

VISIT US FOR MORE AMAZING IMAGES:

SCIENCEFOCUS

BBCSCIENCEFOCUS

CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*

reply@sciencefocus.com

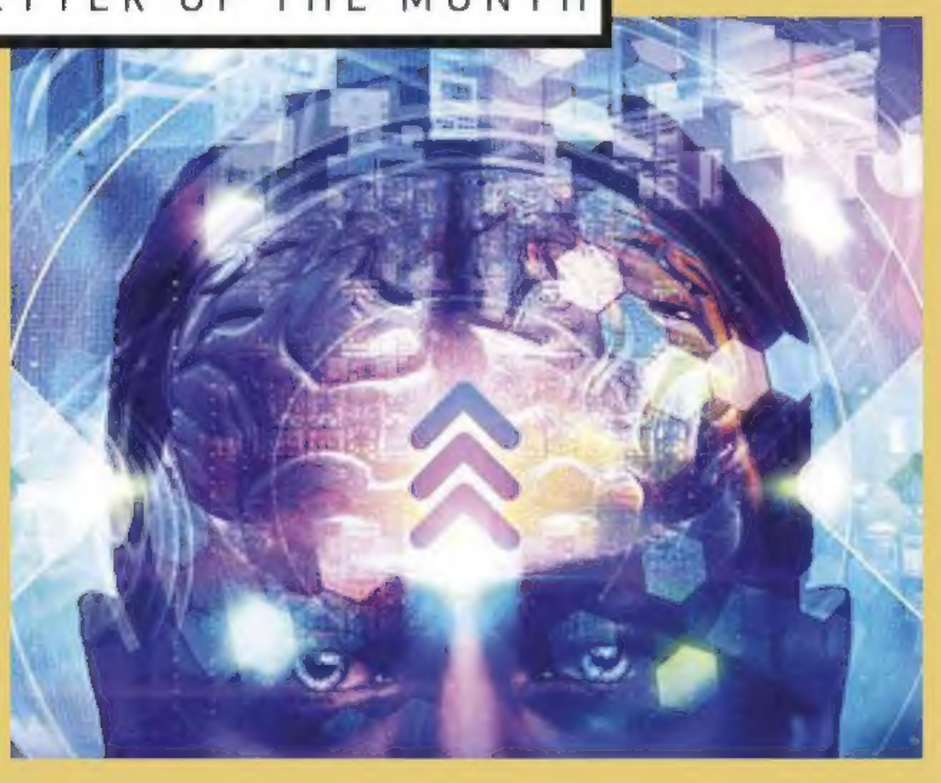
BBC Science Focus, Eagle House, Colston Avenue, Bristol, BS1 4ST

@sciencefocus

www.facebook.com/sciencefocus

@bbcsciencefocus

LETTER OF THE MONTH



Brain upgrade? No, thanks

Lucy Maddox's article 'Should you upgrade your brain?' (October, p72) got me thinking.

As a millennial, technology is the prominent feature of my day-to-day life, from work to social media to hobbies. But I would answer 'no' to upgrading my brain. The benefits seem appealing, with the possibility of remembering things I may not beforehand, or even using it to heighten my own IQ. But where would that lead mankind in the – already feared – future with artificial intelligence? If we can do this to our own brain, how long before the ways of our mind can be used for more harm than good?

Would the enhanced you, really be 'you'?

Rebecca Roskilly, via email

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins a pair of Libratone TRACK+ wireless earphones, worth £149! Weighing just 28g and featuring Active Noise Cancellation, these earphones combine rich sound and a sleek, tangle-free design. Perfect for exercising, TRACK+ let you control how much of the world you let in with CityMix® Smart adaptive noise cancellation, are sweat- and splash-proof (IPX 4), and boast a battery life of eight hours.

libratone.com

It's all in the scent

Although I enjoyed reading 'Hygiene: is there such a thing as too clean?' (October, p33) and its coverage of the 'speck of dirt' theory to explain the allergic march, I'd like to correct an assertion made: 'sweat doesn't smell'. In fact, sweating is an efficient aspect of excretory function, and volatile compounds dissolved in sweat certainly do have distinct odours that can be used to provide diagnostic clues during clinical examination.

David Propert, *London, via email*

It's true that smell is useful for diagnosis when you're unwell, as there can be extra compounds in your sweat that have a scent (see 'Sniffing out disease', Summer, p73). But normally sweat is just water, salts and some oils, and that doesn't smell much, if at all – body odour or 'BO' is caused by germs on the skin that feed on sweat, not by the sweat itself.

Sara Rigby, *online assistant*

Autism discourse

In response to the article about the lack of evidence for a link between testosterone and empathy (October, p15), I'd like to point out that "the capacity to read the emotions of others" being impaired doesn't mean such a person doesn't have empathy, any more than someone who is 'face blind' doesn't have a face.

Martin Petryszyn, *via email*

I enjoyed reading your article about testosterone and empathy in autism. However, when talking about the sex differences in autism, you didn't mention that research also suggests that the reason for fewer girls being diagnosed than boys may be instead due to flaws in the diagnostic process. Research has suggested that girls may find it easier to mask or compensate for autistic traits than boys, and that differences in early social experiences may also play a part.

I'd also like to add that studies have a tendency to treat autism as a single disease – yet in reality it's a spectrum. A high-functioning autistic person and a person with severe difficulties communicating, perhaps to the point of not being able to speak, may not have quite as much in common as the single diagnosis might suggest.

Tamsin Nicholson, *via email*

Thanks for writing in. I suspect what the study and article haven't got across well (due to their brevity) is that cognitive empathy is intertwined with what's sometimes called 'mind-reading' or 'theory of mind'. This is an individual's ability to put themselves in another person's position. Not just in an emotional sense, but in a physical one too. Many people with an autism spectrum disorder (ASD) diagnosis struggle to imagine themselves seeing objects from different perspectives and this core difference, among others, underlines a lot of the difficulties people with ASD face. Having worked with children with ASD, I can confirm they definitely have emotions! And yes, the single diagnosis does disguise the variety, but searching for what unifies people in this spectrum will help us understand what's happening in the brain, and ultimately how to make the world better for people with ASD. There's still a massive amount we simply don't know about the condition.

Daniel Bennett, *editor*

"THE PROBLEM WITH MATHS IS THAT YOU CAN'T SEE IT. YOU CAN'T HOLD IT. YOU CAN'T POINT TO IT AND SAY THAT'S WHAT IT IS. IT'S INVISIBLE."

DR HANNAH FRY, p66

READERS' BUZZ

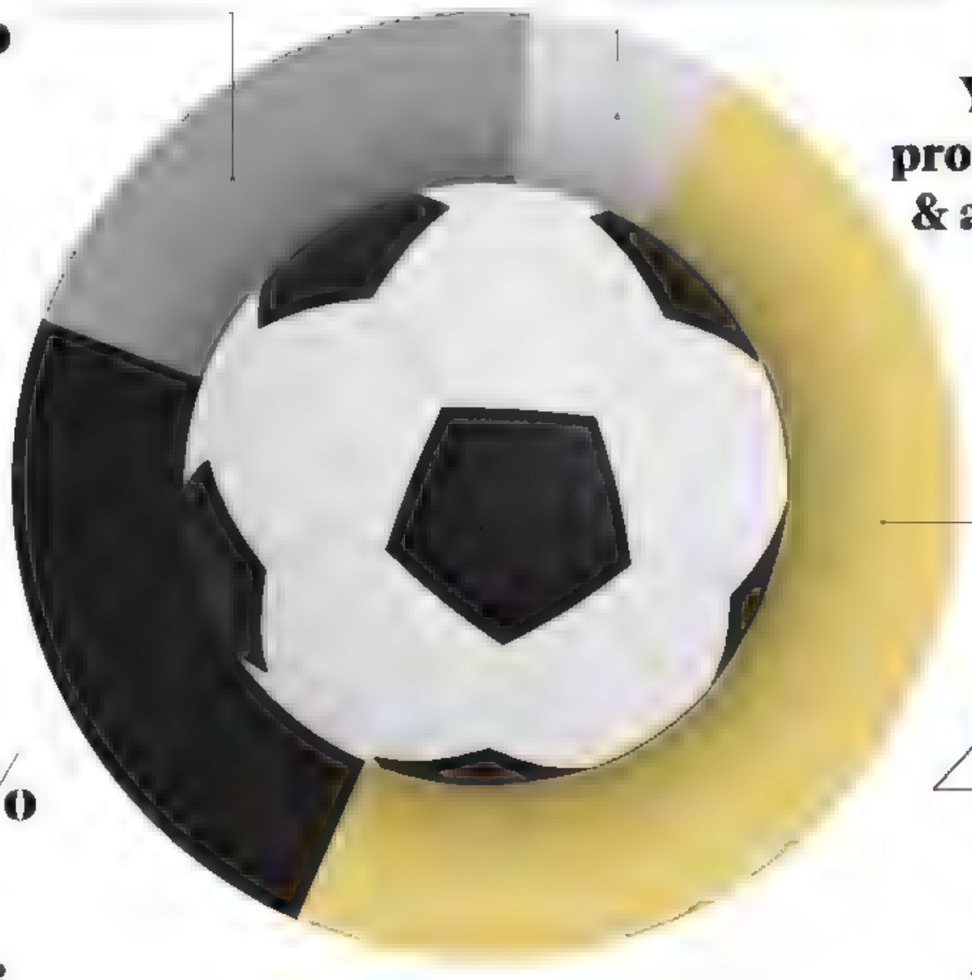
Your views on the burning science topics of the month

After a study showed pro footballers were 3.5 times more likely to die of dementia than the public at large, the Scottish FA announced it was considering a heading ban for under-12s. But does the science support this? We looked at the research in last month's *Reality Check*, then asked our Twitter followers...

SHOULD FOOTBALL PLAYERS BE BANNED FROM HEADING?

21% No, not enough proof

7% Yes, for professionals & amateurs



24% Yes, for players under 23

48% Yes, for players under 12

GETTY IMAGES X2, ANDY POTTS

THE TEAM

EDITORIAL
Editor Dane Bennett
Production editor Alice Lipscombe Southwell
Commissioning editor Jason Goodyer
Staff writer James Lloyd
Editorial assistant Polly Barrett
Online editor Alexander McNamara
Online assistant Sara Rigby
Science consultant Robert Matthews

ART
Art editor Joe Eden
Deputy art editor Steve Boswell
Picture editor James Cutmore

CONTRIBUTORS
Scott Balmer, Ovadia Benshu, Hayley Bennett, Peter Bentley, Chiara Brazzale, Dan Bright, Stuart Clark, Brian Clegg, Charlotte Corney, Simon Crompton, Emma Davies, Rosse Deeks, Sam Falconer, Amy Fleming, Alexandra Franklin-Cheung, Rory Galloway, Alice Gregory, Dr Hilary Cutcliffe, Alastair Gunn, Jules Howard, Adam Hylands, Tom Ireland, Christian Jarrett, Alia Katsneson, Aleks Krotoski, Michael Mosley, Carlos Ortega, Helen Pilcher, Jason Rash, Andy Ridgway, Adam Shaha, Helen Scales, Sébastian Thibault, Jocelyn Timperley, Luis Villazon

ADVERTISING & MARKETING
Group advertising manager Tom Drew
Advertisement manager Sam Jones 0117 300 8145 samjones@immediate.co.uk
Business development manager Dan Long daniel.long@immediate.co.uk
Brand sales executive Hannah Rich hannah.rich@immediate.co.uk
Newstrade manager Helen Seymour
Subscriptions director Jacky Perales-Morris
Direct marketing manager Kellie Lane

MOBILE
Head of apps and digital edition marketing Mark Summerton

INSERTS
Laurence Robertson 00353 876 902208

LICENSING & SYNDICATION
Director of licensing and syndication Tim Hudson
International partners manager Anna Brown

PRODUCTION
Production director Sarah Powell
Production coordinator Katty Skardon
Ad services manager Paul Thornton
Ad coordinator Jade O'Halloran
Ad designer Julia Young

PUBLISHING
Commercial director Jemma Dixon
Content director Dave Musgrove
Managing director Andy Healy
Group managing director Andy Marshall
CEO Tom Bureau

BBC STUDIOS UK PUBLISHING
Chair, editorial review boards Nicholas Brett
Managing director, consumer products and licensing Stephen Davies
Head of publishing Mandy Thwaites
Compliance manager Cameron McEwan
UK publishing coordinator Eva Abramik
Contact UK.Publishing@bbc.com
www.bbcstudios.com

EDITORIAL COMPLAINTS
editorialcomplaints@immediate.co.uk

ANNUAL SUBSCRIPTION RATES (INC P&P)
UK/BFPO £63 Europe & Eire Airmail £66
Rest of World Airmail £70

ABC Audit Bureau of Circulations
50,022 (combined Jan-Dec 2018)

IMMEDIATE MEDIA CO | ipso Regulated

BBC Science Focus Magazine is published by Immediate Media Company London Limited under licence from BBC Studios who help fund new BBC programmes

Stripe OLT

Smart technology for brighter business

Don't give cyber criminals the key to your data this Christmas.

During the festive period, reports of cyber-crime are due to increase and although it may be the season of giving, your data certainly isn't something you want to give cyber-criminals access to.

At Stripe OLT, we specialise in Online Business Security, but this doesn't mean we shouldn't share our knowledge to help keep you cyber-safe this Christmas!

Follow these five cyber-safe top tips and you can stop your personal data from being St-Nicked this Christmas!

Make sure to update your devices.

Start with the basics and make sure your personal devices are up to date! Cyber-Criminals utilise software weaknesses to attack, so don't ignore those update prompts! By staying up to date, you can stay one step ahead.

Utilise 2-factor-authentication.

2-Factor-authentication is essentially just using more than one access method, like PIN and fingerprint, to log into your accounts. Widely available for free, this service can be activated on most popular apps, and you can usually find this in the app security settings.

Look out for phishing e-mails!

This type of e-mail will aim to do two things - either gain your personal data or install dangerous software. So be extra wary and look out for indicators such as suspect language, the use of public e-mail domains and mismatched URLS (to check this one just hover over the link to find out if it's a match).

Download a password manager.

By using a security app like LastPass or BitWarden, there's a place to organise your login details, as well as generate strong passwords that are different for every site. This ultimately makes it much harder for hackers to use or sell your details, because no login will be the same!

Use a safe search engine.

Hackers often create URLs that mimic legitimate websites, so whilst you're online, shopping for those gifts from Santa, make sure you're using a browser like Bing or Google - one that provides reliable links. Alongside this it's always worth checking the URL bar before you make any purchases!

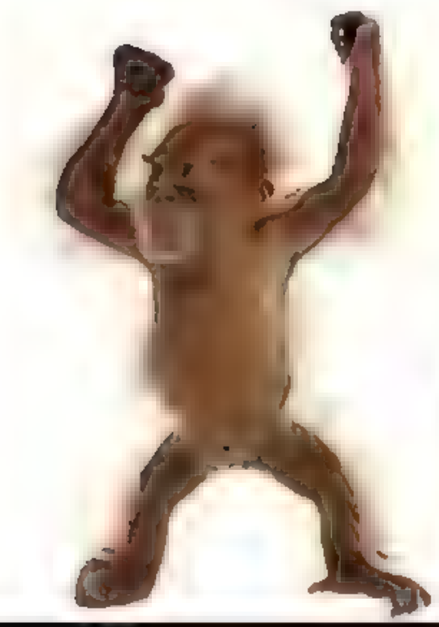
CYBER ESSENTIALS PLUS

Gold Microsoft Partner

Microsoft

For more information on how to protect your business this Christmas visit our website: www.stripeolt.com/cyber-safe-christmas/

London 0207 043 7044 **Bristol** 0117 974 5179



THE JUNGLE VIP
New method reveals genetic secrets of giant ape p15

SHELL SUIT
Microfibres from our clothes are found in shellfish p16

QUICK SMARTS
Experts' brains may be more efficient p17

BIRD BRAINED?
Small-brained birds live in primate-like societies p18

DISCOVERIES

DOCTORS PUT A PATIENT INTO 'SUSPENDED ANIMATION' FOR FIRST TIME

Ground-breaking technique involves rapidly cooling the brain down to 10-15°C

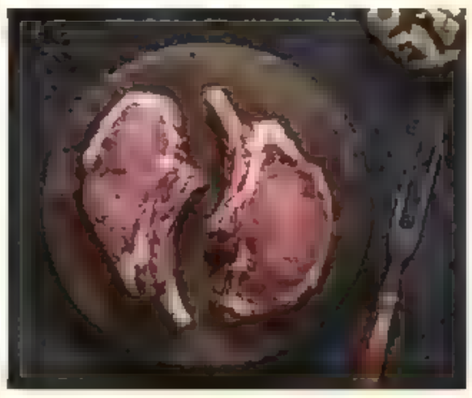
SHUTTERSTOCK

The search is on Scientists use new technique to spot mini black holes p19 **Bad news, kids** Climate change affects children more than adults, according to new survey p20 **End of year roundup** The top science news stories from 2019 p22

News in brief

TRENDY KETO DIET COULD HELP FIGHT FLU

The high-fat, low-carbohydrate ketogenic diet beloved by celebrities may help fight the flu virus, a study at Yale University has found. Mice fed on a ketogenic diet produced gamma delta T-cells – immune system cells that create mucus in the cell linings of the lung that can effectively trap the flu virus, the researchers found. As mouse and human metabolisms are different, it's unclear if the finding will be replicated in humans.



Hypothermic preservation could prevent brain death in critically injured patients who have lost a lot of blood

Researchers in the US have successfully placed a live human patient in 'suspended animation' for the first time, a spokesperson from the University of Maryland has confirmed. It is hoped that the technique could help surgeons to save the lives of patients with severe injuries such as stab wounds or gunshots whose hearts have stopped beating, they say.

The technique, dubbed 'Emergency Preservation and Resuscitation' (EPR), is being tested by a team at the Shock Trauma Center at the University of Maryland Medical Center. It involves pumping ice-cold saline directly into the body via a cannula inserted directly into the aorta to replace the blood being lost. This induces a deep state of 'hypothermic preservation' – as low as 10-15°C – not unlike the state known in science fiction as 'suspended animation'. This is not cooling by a few degrees after a carefully controlled cardiac resuscitation; it is more like freezing someone and operating on them while they are technically dead.

"We have developed EPR using hypothermia to decrease the body's need for oxygen and blood flow"

Normally, doctors would expect somebody with no blood reaching the brain to die or suffer irreversible brain damage within five minutes, but with EPR patients can potentially be kept alive for upwards of two hours. Once the lifesaving surgery has been completed, the patient is gradually warmed back up to a body temperature of 37°C.

"Trauma patients who lose so much blood that the heart stops very rarely survive, even with blood transfusions and CPR. We have developed Emergency Preservation and Resuscitation using hypothermia to decrease the body's need for oxygen and blood flow to see if we can buy time to save these patients who are dying in front of us," said Prof Samuel Tisherman, who led the research team. "We are currently looking at the safety and feasibility of the EPR cooling technique. Our main goal is to demonstrate that we can do it and that it works."

Tisherman presented the findings of the ongoing clinical trial at a research event held at the New York Academy of Sciences. The study hopes to compare the outcomes of 10 patients who received the 'hypothermic preservation' treatment with 10 who received traditional emergency treatment and is due for completion by the end of 2020.

So far, the technique has reportedly only been used to successfully place a patient into the 'hypothermic preservation' state. It is not clear whether or not the patient survived the resulting operation.

RENEWABLE ENERGY
This really blew our socks off: global wind speeds have increased by almost 20 per cent over the past decade, a study at Princeton University has found. The change may enable more widespread use of wind energy, say the researchers.

65-YEAR-OLDS
You may not be as old as you think! The unofficial onset of old age should be bumped up from 65 to 70, the Office for National Statistics says. The change is due to increases in life expectancy meaning that more and more of us are living into our 80s, they say.

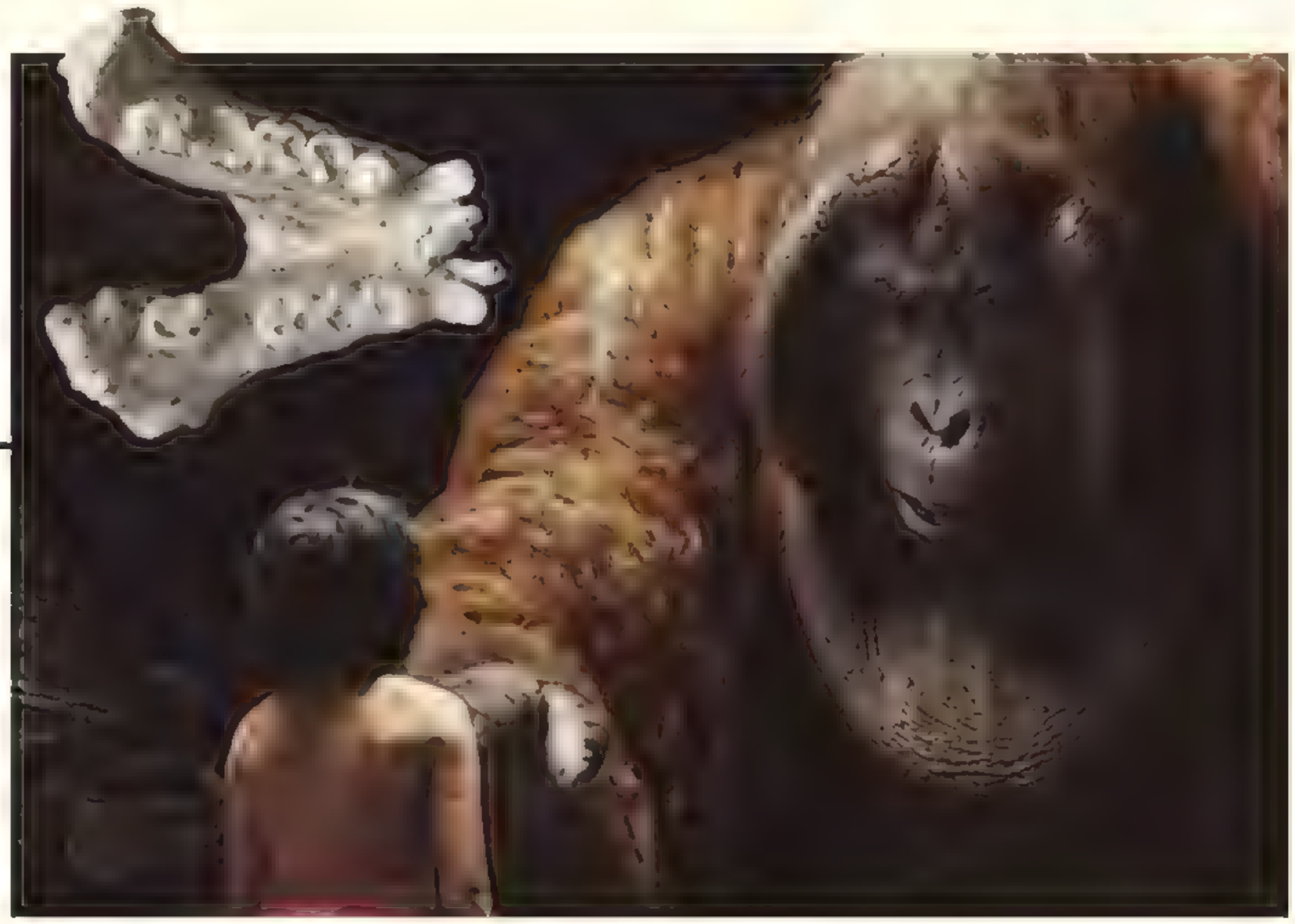
Good month

Bad month

INSECTS
Artificial light at night-time is causing a serious decline in the numbers of moths, beetles, wasps and other insects that have evolved to use light levels as cues for courtship, foraging and navigation, a study at Washington University has found.

HELICOPTER PARENTS
Mums and dads who take an excessive, overbearing interest in their children's development may be raising youngsters with low levels of "mastery, self-regulation and social competence", a study at West Virginia University suggests.

GETTY IMAGES, SHUTTERSTOCK, PROFESSOR WEI WANG ILLUSTRATION CHIARA BRAZZALE



Gigantopithecus blacki was the inspiration behind King Louie in Disney's live action *The Jungle Book*. Genetic material extracted from fossilised *G. blacki* teeth (inset) has helped scientists get a clearer picture of how the species fits into the primate family tree

EVOLUTION

New technique proves extinct giant ape was direct relative of orangutan

Gigantopithecus blacki, a three-metre-tall, 600kg, two-million-year-old ape, was related to the modern-day orangutan.

The discovery was made by researchers at the University of Copenhagen's Globe Institute using protein sequencing techniques on a group of *Gigantopithecus* fossils found in southern China in 1935. As there are only a few lower jaws and teeth to go on – no complete skulls or other bones – there has been a lot of speculation about exactly what this mysterious animal would've looked like.

The team made the discovery using cutting-edge mass spectrometry techniques to examine proteins in the enamel of the fossilised teeth, and extract genetic information about the ancient animal's lineage. This marks the first time that genetic material this old has ever been retrieved from a warm, humid environment.

"By sequencing proteins retrieved from dental enamel that's about two million years old, we showed it is possible to confidently reconstruct the evolutionary relationships of animal species that went extinct too far away in time for their DNA to survive till now. In this study, we can even conclude that the lineages of orangutan and *Gigantopithecus* split up about 12 million years ago," said the Globe Institute's associate professor Enrico Cappellini, who was a senior author on the study.

The success of the new technique opens up possibilities to extend the genetic reconstruction of the evolutionary relationships between humans and extinct ancestral species further back in time, at least up to two million years – covering a much larger portion of human evolution than was previously possible.

"Primates are relatively close to humans, evolutionarily speaking. With this study, we show that we can use protein sequencing to retrieve ancient genetic information from primates living in subtropical areas, even when the fossil is two million years old. Until now, it has only been possible to retrieve genetic information from up to 10,000-year-old fossils in warm, humid areas," said Globe Institute postdoctoral researcher Frido Welker. "This is interesting, because ancient remains of the supposed ancestors of our species, *Homo sapiens*, are also mainly found in subtropical areas, particularly for the early part of human evolution. This means that we can potentially retrieve similar information on the evolutionary line leading to humans."

DON'T BE SHELLFISH, SWITCH TO PLASTIC-FREE CLOTHING

Plastic microfibres thought to be from clothing and fishing gear have been found in oysters and clams, a recent study at Portland State University shows. These microplastics were found in 99 per cent of the Pacific oysters and razor clams sampled by the researchers. The molluscs tested were collected along the Oregon coast. It is a common conception that discarded fishing equipment makes up a huge amount of the plastic in the oceans; however, the researchers of this new study claim it is microfibres from synthetic and natural materials in our clothing that have found their way into the shellfish.

Trending

YOUR GUIDE TO WHO'S SAYING WHAT ABOUT THE HOTTEST TOPICS IN THE WORLD RIGHT NOW

#Uber

The popular taxi app service will not be granted a new licence to operate in London, Transport for London has announced. They cite safety issues as the primary reason. Uber is now appealing against the decision.

Charles Holland
@charlesholland

TfL: A key issue was that a change to Uber's systems allowed unauthorised drivers to upload their photos to other Uber driver accounts. This allowed them to pick up passengers as though they were the booked driver, which occurred in at least 14,000 trips.

Alexander Meleagrou-Hitchens
@amhitchens

People celebrating this #Uber news in London should know that this is a terrible development for many hard-working migrants in London.

KEEP IN TOUCH

@SCIENCEFOCUS

#SumatranRhino

The Sumatran rhino has gone extinct in Malaysia. Iman, the last of the species, died of cancer this month. There are now fewer than 100 animals left, with most living in Sumatra, Indonesia.

Kathryn Jeffs
@kathrynjeffs

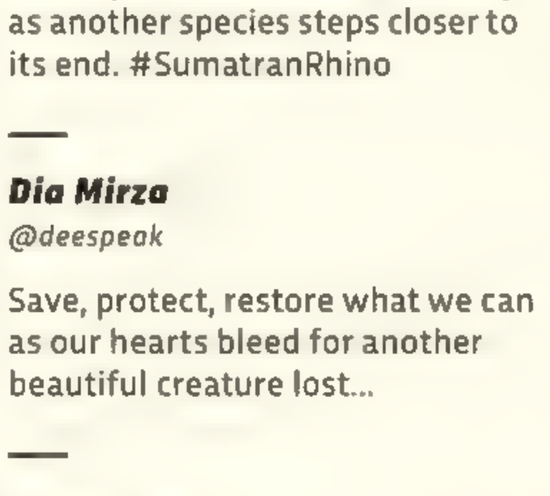
A punch to the stomach... that's the only way I can describe how reading this felt. Head is spinning as another species steps closer to its end. #SumatranRhino

Dia Mirza
@deespeak

Save, protect, restore what we can as our hearts bleed for another beautiful creature lost...

Ricky J Lee
@DrRickyLee

I am so disappointed to read of the death of the last #SumatranRhino in Malaysia. The critically endangered species now numbers only between 30 to 100. We must do more to combat deforestation, poaching and habitat loss.



#Cybertruck

Earlier this month Tesla CEO Elon Musk unveiled his new semi-autonomous, battery-powered pickup. Despite its futuristic, angular design being divisive, the company says it has already received more than 200,000 orders for the vehicle.

Brad Garcia
@bradgarcia

The #Tesla #Cybertruck is Tesla's ultimate first-principles design. And it was done with the main goal of minimising production costs. This is the only way a truck with all of these capabilities can be sold profitably at $40,000.

Cali PhD
@C4liCrypto

Tesla #Cybertruck is running on the lowest graphics settings.

Jeff Piotrowski
@Jeff_Piotrowski

This is my next storm-chasing vehicle – #Tesla #Cybertruck

#AustralianBushfires

The wildfires that have been raging across southeastern Australia have wiped out hundreds of wild koalas. It is estimated that there are currently only a few hundred thousand of the marsupials left, putting them in the 'vulnerable' category on the IUCN Red List of Threatened Species.

Melissa Weir
@tazsgal

This made me tear up, knowing how much of our wildlife is in this situation while such massive fires turn our country into ashes #koalarescue #koala #koalabear #AUSTRALIANBUSHFIRES #bushfires

polar.rack
@WolfgangRack

Snowpit measurement at Rolleston Glacier in the Southern Alps [on New Zealand's South Island]. Recent Australian bushfires from 2,000km away left a substantial dust layer.

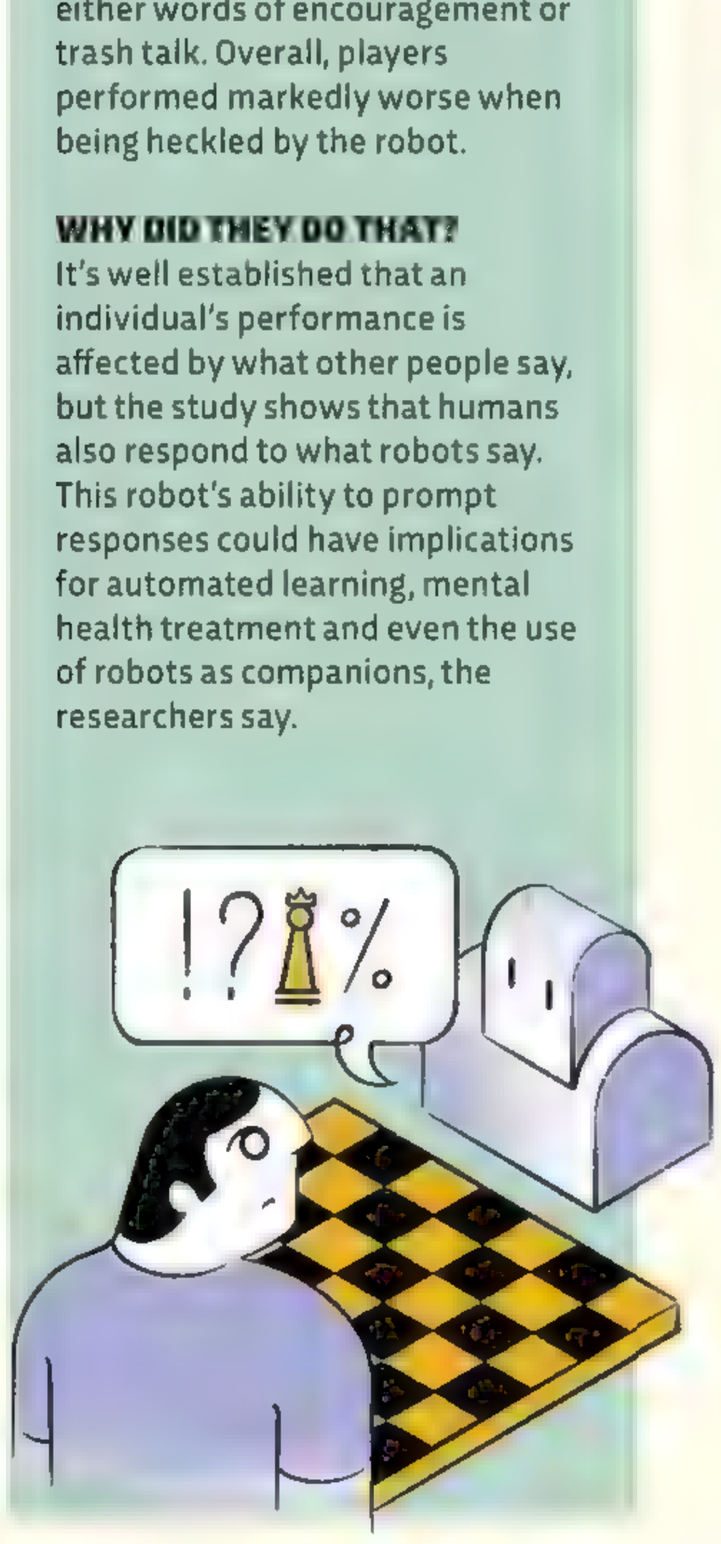
They did what?

Gamers trash-talked by robots

WHAT DID THEY DO?
Researchers at Carnegie Mellon University trained a commercially available humanoid robot known as Pepper to heckle human participants as they played a simple video game against one another. The insults used were very mild and included such minor slights as "I have to say you are a terrible player," and "Over the course of the game your playing has become confused."

WHAT DID THEY FIND?
Each of the 40 participants played with the robot 35 times, receiving either words of encouragement or trash talk. Overall, players performed markedly worse when being heckled by the robot.

WHY DID THEY DO THAT?
It's well established that an individual's performance is affected by what other people say, but the study shows that humans also respond to what robots say. This robot's ability to prompt responses could have implications for automated learning, mental health treatment and even the use of robots as companions, the researchers say.



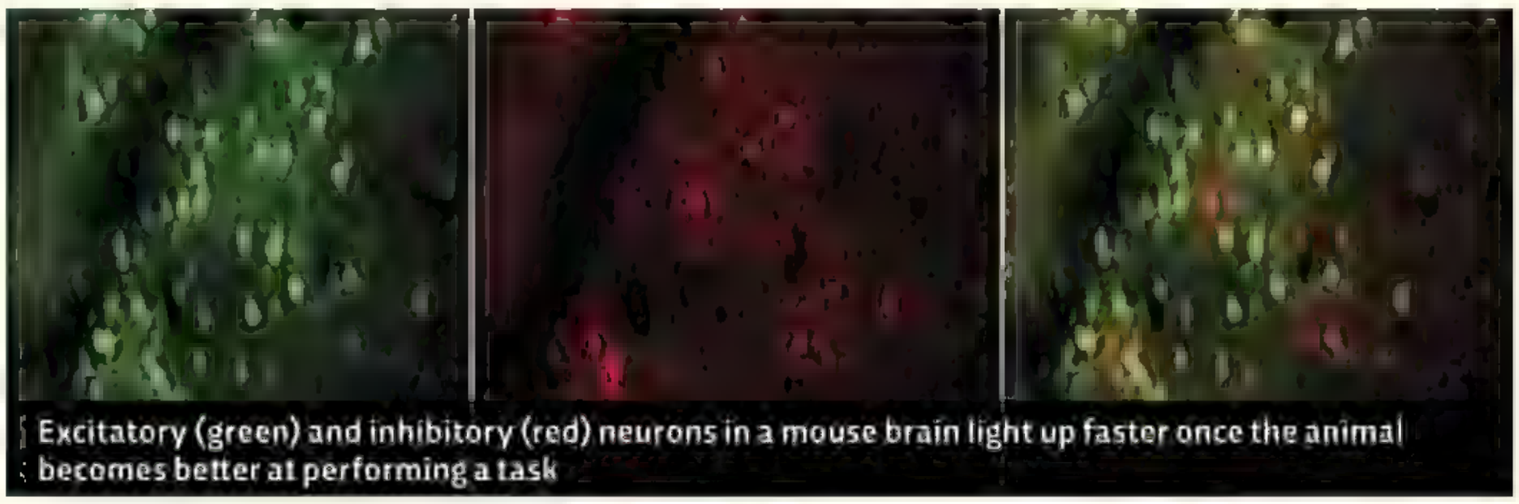
GETTY IMAGES X5, ALAMY ILLUSTRATIONS CHIARRA BRAZZLE

BREAST CANCER COULD BE DETECTED EARLY USING A BLOOD TEST

A simple blood test could be used to detect breast cancer up to five years before there are any clinical signs of it. Researchers at the University of Nottingham have developed a test that identifies proteins produced by the body's immune response to tumour cells linked to breast cancer.

PSYCHOLOGY

Experts' brains have faster, more efficient neurons, mouse study suggests



Excitatory (green) and inhibitory (red) neurons in a mouse brain light up faster once the animal becomes better at performing a task

Mastering a new skill can take hours of dedicated practice. Now, a team of researchers studying mice at Cold Spring Harbor Laboratory in New York have shed light on what happens in the brain as a new skill is acquired by successfully mapping the changes that occur in the wiring of cell circuits and the performance of neurons.

The finding could lead to a deeper understanding of how learning a skill alters different parts of the brain and maybe even lead to new methods to improve learning, they say.

The team trained the mice to respond to a series of flashes and clicks by licking one of three waterspouts in front of them. They licked the middle spout to start the trial, one side to report a high rate of clicking and flashing and the other side to report a low rate of flashing and clicking. When the mice made the correct decision, they received a reward.

The researchers then monitored the mice's brains over the course of several weeks using state-of-the-art imaging techniques, tracking the changes as the mice got better and better at the task.

"We recorded the activity from hundreds of neurons all at the same time, and studied what the neurons did over learning," said associate professor Anne Churchland, the senior author on the study.

Over time, the neurons used by the mice in the task became more fine-tuned, only firing when the correct decision was made, and also started to react more quickly. When the animals were just beginning to learn, the neurons didn't respond until around the time the mouse made the choice. But as the animal gained experience, the neurons responded much further in advance, indicating a higher level of expertise.

"Most decision-making studies focused on the period where the animals are really experts. But we were able to see how they arrive at the state by measuring the neurons in their brain all the way through learning," said Churchland. "We found that in all the animals, their learning occurs gradually over about four weeks. And we found that what supports learning is activity changes in a whole bunch of neurons."

TERRIBLE TWOS WORSE IN LATE TALKERS

Toddlers who start talking late are nearly twice as likely to have severe temper tantrums – hitting, kicking and holding their breath – which can show a risk of mental health and behavioural problems further down the line, a study at Northwestern University has found. Little 'uns who have these tantrums on a daily basis may need help managing their temper, though the researchers behind the study have warned parents not to overreact if their infants are prone to grumbling.

Children are considered 'late talkers' if they have not started putting words together by the time they are two years old, said researchers, and these language problems can also affect their education and performance in the future.

In numbers

27 PER CENT

The amount by which harmful air pollution can be reduced by planting trees near to factories, a study at the Ohio State University has found.

2100

The year emperor penguins could go extinct due to the effects of climate change, as estimated by researchers at the Woods Hole Oceanographic Institute.

40 PER CENT

The jump in productivity seen by Microsoft Japan when it switched to a four-day working week for the month of August.

ZOOLOGY

Small-brained birds live in surprisingly complex societies

Previously, it was thought that complex, multi-level societies comprising many different hierarchical positions were unique to humans and a select group of other large-brained mammals. Now, research at Germany's Max Planck Institute has found that vulturine guineafowl – large, bald-headed birds found in forests in eastern Africa – also display evidence of forming multi-level societies, despite having tiny brains.

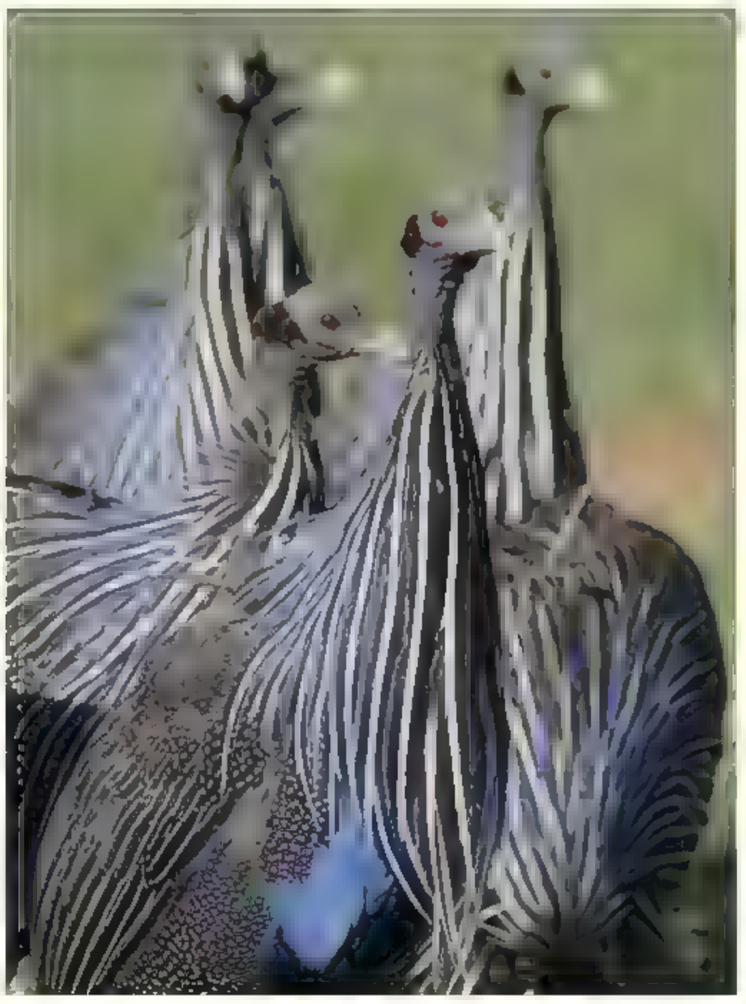
> **"This is the first time a social structure like this has been described for birds"**

"To our knowledge, this is the first time a social structure like this has been described for birds," said PhD student Danai Papageorgiou, who led the research. "It's quite remarkable to observe hundreds of birds coming out of a roost and splitting up perfectly into completely stable groups, every single day. How do they do that? It's obviously not just about being smart."

Multi-level societies occur when animals in a larger group form smaller groups that interact differently with other specific groups – by mating, communicating or fighting, for example. Because this requires the animals to keep track of individuals in their own and other groups, the assumption has long been that such societies should only exist in species with the intelligence to cope. While many bird species do live in large groups, these lack long-term stability or are highly territorial, and so lack meaningful associations with other groups.

For the study, the researchers tracked 400 adult birds over multiple seasons in a field in Kenya. They found that the birds were split into 18 distinct social groups, each consisting of between 13 and 65 individuals. These groups remained stable for the duration of the whole study, and associated with each other based on clear preferences rather than random encounters.

"This discovery raises a lot of questions about the mechanisms underlying complex societies, and has opened up exciting possibilities of exploring what is it about this bird that has made them evolve a social system that is, in many ways, more comparable to a primate than to other birds," said senior researcher Dr Damien Farine.



Vulturine guineafowl live in complex societies in Ethiopia, Tanzania and Kenya

Artist's impression of a black hole shredding a star

ASTRONOMY

Scientists hunt mini black holes

It appears that a whole population of miniature black holes might be lurking unsuspected in the cosmos.

The discovery came after an international team of astronomers developed a new way to search for black holes. These mysterious cosmic entities – which have a gravitational pull so strong that nothing, not even light can escape it – form when massive stars collapse at the end of their life. If a dying star is below a certain mass, on the other hand, it will collapse not into a black hole but into a small, dense neutron star.

Neutron stars are generally no bigger than about twice the mass of the Sun – were they any bigger, they'd collapse into a black hole. However, all of the stellar black holes that astronomers have discovered so far have a mass at least five times that of the Sun. This clearly leaves a gap between the biggest neutron stars and the smallest known black holes, and that gap has remained stubbornly unfilled – until now.

The new technique makes use of the fact that black holes can often be found in a binary system, where two stars are locked together in mutual orbit. If one of the stars dies and becomes a black hole, it can stay in the system, its presence revealed by changes in the living star's light spectrum as it orbits its invisible companion.

The researchers used data from APOGEE (the Apache Point Observatory Galactic Evolution Experiment), which collected light spectra from around 100,000 stars across the Milky Way, and homed in on 200 stars that looked like they might be orbiting a black hole. Further data-crunching then revealed a 'red giant' star orbiting a low-mass black hole, estimated to be about 3.3 times the mass of the Sun.

"What we've done here is come up with a new way to search for black holes," said Prof Todd Thompson from Ohio State University, who was lead author of the study. "But we've also, potentially, identified one of the first of a whole new class of low-mass black holes that astronomers hadn't previously known about," he added.

"If we could reveal a new population of black holes," he continued, "it would tell us more about which stars explode, which don't, which form black holes, and which form neutron stars. It opens up a new area of study."

GETTY IMAGES X2, JAMES KLAREVAS

GREEN PAPERS

The environmental stories you need to know

Climate change hits kids hardest, says a new report

'CLIMATE EMERGENCY' NAMED WORD OF THE YEAR

Oxford Dictionaries has declared the phrase 'climate emergency' its Word Of The Year 2019. The expression was used over 100 times more in September 2019 than in September 2018, and became by far the most written-about form of emergency, with over three times as many mentions as 'health emergency,' the second most-mentioned.

Oxford Dictionaries defines 'climate emergency' as "a situation in which urgent action is required to reduce or halt climate change and avoid potentially irreversible environmental damage resulting from it."

CLIMATE

Children among the worst hit by climate change

Damning international survey highlights urgent need for action

The world is seeing rising health risks linked to climate change, with children and pensioners particularly impacted, says a major new report created by medical journal *The Lancet*.

According to the report, children are more susceptible to disease, environmental pollutants and malnutrition since their bodies and immune systems are still developing. Meanwhile, pensioners are increasingly at risk from the growing threat of heatwaves. The number of over 65s exposed to heatwaves globally was 220 million higher in 2018 than in 2000, says the report, which is a collective research effort from 120 authors and 35 global institutions.

"When we look at the indicators of the links between climate change and health, what we see is the indicators going in the wrong direction," says Elizabeth Robinson, professor of environmental economics at the

VENICE FLOODS

Venice's regional council flooded just minutes after it rejected measures to combat climate change. "Ironically, the hall flooded two minutes after the majority League, Brothers of Italy and Forza Italia parties rejected our amendments to fight climate change," said local councillor Andrea Zanoni in a Facebook post.

The city saw its worst flooding in over 50 years in November. Extreme high tides, strong storms and the city's slow sinking were all contributing factors. The city's mayor, Luigi Brugnaro, blamed the floods on climate change, though others say damage could have been limited had planned flood defences not been delayed.

University of Reading and a co-author of the report.

Damage done in early childhood can lead to lifelong health consequences, the report warns. For example, air pollution is especially damaging to young people, since their lungs are still developing. Likewise, infants are particularly hit by malnutrition and related long-term health problems, such as stunted growth and weak immune systems. Children are also very susceptible to infectious diseases, such as dengue fever, which are increasing due to rising temperatures and changing rainfall patterns.

Gautam Narasimhan, a senior adviser on climate at UNICEF, says his organisation sees the daily impacts of climate change on children's lives in most countries worldwide, with the poorest, most vulnerable communities often bearing the worst effects.

"The report highlights the urgent need for change, but also points to some positive signs"

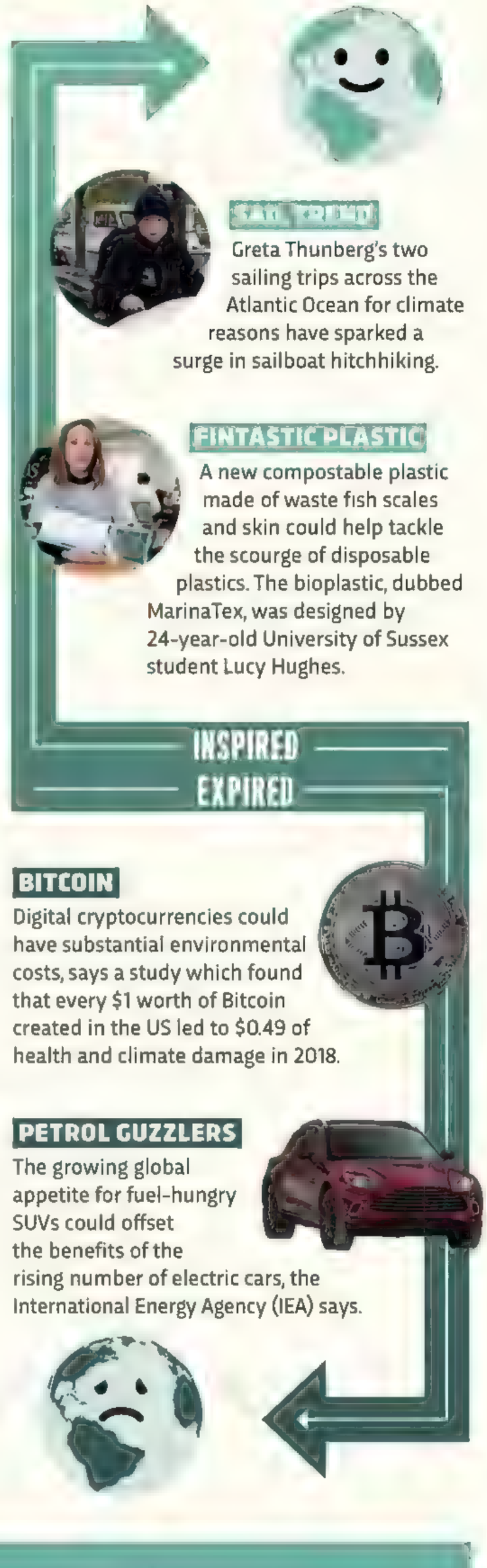
"[Climate change] has the potential to undermine children's rights and threaten gains made in child survival and development in recent decades," he says. "Unless urgent action is taken to reduce emissions to mitigate climate change and support communities in building resilience, the worst for many children is yet to come."

POSITIVE STEPS

The report highlights the urgent need for change, but also points to some positive signs, such as increasing investment in clean energy technologies, and a rising awareness of the dangers of air pollution in cities.

The key message from the study, says Robinson, is that countries do have options when it comes to climate change. For example, she argues, there is a rising awareness that there is an alternative to simply putting up with air pollution in cities.

"We know the problem, we know the solutions, so it's all about political will," she says. "Imagine if governments just stopped subsidising fossil fuels, took that money and invested instead in clean energy and public transport, and in giving low-income households well insulated houses."



SAILING SOLUTION

Greta Thunberg's two sailing trips across the Atlantic Ocean for climate reasons have sparked a surge in sailboat hitchhiking.

FINTASTIC PLASTIC

A new compostable plastic made of waste fish scales and skin could help tackle the scourge of disposable plastics. The bioplastic, dubbed MarinaTex, was designed by 24-year-old University of Sussex student Lucy Hughes.

INSPIRED EXPIRED

BITCOIN

Digital cryptocurrencies could have substantial environmental costs, says a study which found that every $1 worth of Bitcoin created in the US led to $0.49 of health and climate damage in 2018.

PETROL GUZZLERS

The growing global appetite for fuel-hungry SUVs could offset the benefits of the rising number of electric cars, the International Energy Agency (IEA) says.

GETTY IMAGES X4, NEWSPRESS, UNIVERSITY OF SUSSEX

IT'S EASY BEING GREEN

REDUCING YOUR FLIGHT FOOTPRINT

If you fly often, your carbon footprint increases greatly. People are increasingly aware of this issue, with campaigns like Flight Free 2020 asking people to take the train instead, but if you can't avoid flying, there are still things you can do.

Flying in economy class leads to only around half the emissions that arise from flying business class, while newer aeroplanes will generally have a lower fuel burn than older craft. Flying direct, with no layovers, will also generate less emissions.

Ultimately, though, the lowest emission flight is still the one you don't take.

2019's landmark breakthroughs

Here's our pick of the biggest news stories of the last 12 months

SPACE

First plant grown on the Moon

China's Chang'e 4 was the first probe to land on the far side of the Moon. It aimed to test whether we could grow plants on another world

On 3 January, China's Chang'e 4 became the first lunar probe to land on the far side of the Moon. Onboard was the Lunar Micro Ecosystem biosphere experiment, containing air, water, soil and various organisms. Shortly after landing, the experiment was powered up, the internal temperature was adjusted to 24°C, and the seeds watered.

Twelve days later, the Advanced Technology Research Institute at Chongqing University reported that cottonseed, rapeseed and potato seed had sprouted, though only images of the cottonseed were released. The success was short-lived, however, when the following day it was reported that the shoots had failed to survive the freezing temperature of the lunar night. None of the other organisms in the biosphere – mouse-ear cress, yeast or fruit fly eggs – showed any signs of life and the experiment was called off just several days into its planned 100-day stint.

The successful harvesting of plants is seen as a vital part of any long-term space mission, such as establishing a permanent base on the Moon, or even a manned mission to Mars.

China's next mission, Chang'e 5, is scheduled for launch in 2020. It will attempt to collect samples of lunar rock and soil from the surface of the Moon and return them to Earth. There are also whispers that China's space agency has ambitions to build a station near to the Moon within the next decade.

Why do we only ever see one side of the Moon?

Earth's gravity slowed the Moon's rotation on its axis u

What are HIV and AIDS?

HIV (human immunodeficiency virus) is a type of virus that causes damage to cells in the human immune system, weakening its ability to fight off infection and disease. AIDS (acquired immune deficiency syndrome) is the name used to describe the potentially life-threatening illnesses that can arise when the immune system has been significantly damaged by HIV. AIDS cannot be transmitted from one person to another, but HIV can through unprotected sexual activity or the sharing of needles or syringes.

CNSA/CHONGQING UNIVERSITY/GETTY IMAGES

HEALTH

HIV transmission effectively stopped

Conclusive findings of an eight-year study stated that men on antiretroviral HIV treatment have a zero risk of passing on the virus

An antiretroviral treatment developed by researchers at University College London (UCL) and the University of Copenhagen reduced the possibility of passing on the virus that causes AIDS to zero, it was reported in May.

The study, named PARTNER2, involved nearly 1,000 European gay male couples in which one partner was HIV-positive and the other HIV-negative. Over the course of the eight-year study, the couples reported having sex without the use of condoms nearly 80,000 times. None of them was found to pass on the virus to the HIV-negative partner. The researchers estimated that based on the type and frequency of sexual contact, the treatment prevented around 500 HIV transmissions.

"Our findings support the message of the international U=U [undetectable = untransmittable] campaign, that a suppressed viral load makes HIV untransmittable. This message has been endorsed by more than 780 HIV organisations in 96 countries and can help end the HIV pandemic by preventing HIV transmission and tackling the stigma and discrimination that many people with HIV face," said lead researcher Prof Alison Rodger, who is based at UCL's Institute for Global Health.

Antiretroviral drugs work by stopping a virus from replicating in the body, allowing the nervous system to recover, therefore preventing further damage. The measure of the number of viral particles present in a given person's bloodstream is known as a 'viral load' and is expressed as the number of copies of the virus found in one millilitre of blood.

In the PARTNER2 study, the treatment kept the viral loads of the HIV-positive participants at fewer than 200 copies per millilitre. When not on antiretroviral treatment, viral load can reach several millions. For anyone on antiretroviral treatment therapy, the aim is to keep the viral load as low as possible. "Increased efforts must now focus on wider dissemination of this powerful message and ensuring that all HIV-positive people have access to testing, effective treatment, adherence support and linkage to care to help maintain an undetectable viral load," said Rodger.

Ahead of World Aids Day in December this year, the world's first HIV-positive sperm bank, Sperm Positive, was launched in New Zealand in an effort to reduce the stigma of those living with the virus. It will accept donations from those living with HIV who have an undetectable viral load.

SPACE

Life could exist among the stars

A team recreated interstellar clouds in the lab, and found hints of DNA in the process

Simple molecules that make up the basic units needed for life could have formed in the giant clouds of gas lingering between stars, a study by Japanese researchers found in October.

Compounds called nucleobases, the essential building blocks that make up DNA, have been detected for the first time in a lab-based simulation designed to mimic the gaseous clouds that are found in the vast areas of space between stars. The finding brings us closer to understanding the origins of life on Earth, the researchers say. "This result could be key to unravelling fundamental questions for humankind, such as what organic compounds existed during the formation of the Solar System and how they contributed to the birth of life on Earth," said Dr Yasuhiro Oba of Hokkaido University's Institute of Low Temperature Science.

The basic structural unit of DNA is called a nucleotide and is composed of a nucleobase, a sugar, and a phosphate. Previous studies mimicking the conditions expected in interstellar molecular clouds have detected the presence of sugar and phosphate, but never nucleobases.

To make the discovery, the team set up a simulation of an interstellar molecule cloud by pumping a gaseous mixture of water, carbon monoxide and ammonia into a vacuum chamber filled with simulation cosmic dust and cooled it to -263°C. They then shone a pair of specially designed ultraviolet lamps into the chamber to kick-start chemical reactions. This led to an icy film forming on the surface of the dust.

Next, they warmed this substance up to room temperature and analysed its chemical composition using a high-resolution mass spectrometer. They were able to identify the presence of several nucleobases including cytosine, thymine and adenine – three of the four bases that make up all DNA. They also identified several amino acids, which are the building blocks of proteins, another key element for the formation of life.

The team suspects that past experiments simulating interstellar molecular cloud environments would have produced nucleobases, but that the analytical tools used were not sensitive enough to detect them in complex mixtures.

"Our findings suggest that the processes we reproduced could lead to the formation of the molecular precursors of life," said Oba. "The results could improve our understanding of the early stages of chemical evolution in space."

How does DNA work?

billion rung

PALAEONTOLOGY

Dinosaurs' demise deciphered

Scientists drilled into the crater formed by the asteroid that smashed into the planet 66 million years ago

The asteroid that led to the extinction of all non-avian dinosaurs slammed into the Gulf of Mexico's Yucatán Peninsula some 66 million years ago. Then in 2016, a scientific drilling project by the International Ocean Discovery Program retrieved rocks from the impact site, which is submerged offshore.

In September this year, a group of researchers based in the US announced they had used the rocks to piece together an account of what happened on the first day of the dinosaurs' demise. "It's an expanded record of events that we were able to recover from within ground zero," said Dr Sean Gulick, a geophysicist at the University of Texas at Austin and leader of this study. "It tells us about impact processes from an eyewitness location."

In just 24 hours following the impact, material to a depth of 130 metres was deposited. This included charcoal, which provides evidence for the intense wildfires that are thought to have been ignited by the blast. Meanwhile, the impact also triggered a huge tsunami, as evidenced by jumbles of rock and layers of sand in the core samples, which appear to have been deposited by resurging waters.

One thing conspicuously missing from the samples, though, is sulphur. Although the surrounding area is full of sulphur-rich rocks, the crater is sulphur-free. This supports the idea that the asteroid impact instantly vaporised sulphurous rocks, releasing the sulphur into the atmosphere. It lingered there, and reflected away the Sun's light, cooling the Earth's climate.

Although the impact had devastating effects on a regional level, it's this large-scale global cooling that's thought to be behind the dinosaurs' eventual demise, as well as countless other species.

PHYSICS

Black hole photographed

Event Horizon Telescope captured first-ever image of black hole

In April, the first image of a black hole was released by the Event Horizon Telescope (EHT) Collaboration, an international organisation made up of scientists from 40 countries. They captured the image of the supermassive black hole found at the centre of M87, a supergiant elliptical galaxy located in the constellation Virgo. The researchers were awarded The Breakthrough Prize in Fundamental Physics in September, bagging them $3m in prize money.

A black hole is dark because its gravitational pull is so immense that no light can escape. What shows up in the image is the material surrounding the event horizon, often known as the 'point of no return', around the black hole.

Inside the event horizon, any matter or light is doomed to fall inwards. However, outside the event horizon, material swirls around the black hole at near light speed. Gravity and friction heat up the matter, which then glows with radio waves. It was these radio waves that were collected by the EHT.

The data was gathered over the course of a week-long series of observations, using eight telescopes in cooperation. At 55 million light-years from Earth, the supermassive black hole appears far too small in the sky for any one telescope to capture on its own. To pick out the tiny target, the EHT Collaboration combined the resolving power of eight telescopes around the world, effectively creating a virtual telescope the size of the Earth that can image objects that appear a million times smaller than the edge of a razor blade held at arm's length.

Event horizons are among the most extreme environments in the Universe, and any unexpected observations could point to previously undiscovered physics.

NASA/HUBBLE SPACE TELESCOPE, GETTY IMAGES, EVENT HORIZON TELESCOPE

PC Specialist recommends Windows Windows 10

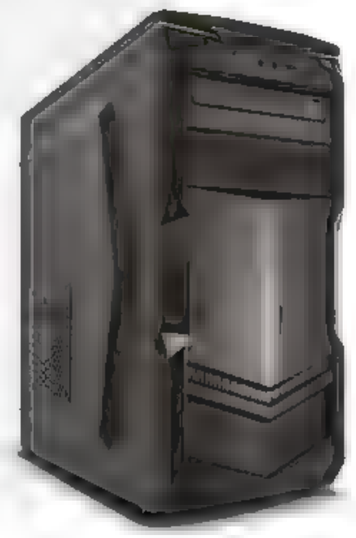
PROTEUS VI RTX

15.6" Matte Full HD IPS Screen
Intel® Core™ i7-8750H
16GB Kingston DDR4 2133MHz
8GB GeForce RTX 2070
1TB SEAGATE 7mm SATA HDD (7,200)
Genuine Windows 10 Home

This spec from
£1,349.99

VORTEX ELITE

PCS 6003B BLACK GAMING CASE
Intel® Core™ i3-8100
ASUS® H310M-A
8GB Corsair VENGEANCE 2400MHz
2GB GEFORCE GTX 1050
Genuine Windows 10 Home



This spec from
£529.99

DEFIANCE V RTX

17.3" Matte Full HD 144Hz Screen
Intel® Core™ i7-8750H
16GB Corsair 2133MHz
8GB GeForce RTX 2070 Max-Q
1TB SEAGATE 7mm SATA HDD (7,200)
Genuine Windows 10 Home

This spec from
£1,449.99

ILLUSION ELITE

THERMALTAKE V200 RGB TG
AMD Ryzen 7 2700X
ASUS® TUF X470-PLUS GAMING
16GB Corsair VENGEANCE 2400MHz
16GB AMD RADEON™ VII
Genuine Windows 10 Home

This spec from
£1,689.99

GET A FURTHER £15 OFF WITH THIS EXCLUSIVE VOUCHER CODE: **BBF19**

0333 011 7000

Some features require Windows 10. Update available through Windows Store. Internet access required; fees may apply.
Microsoft, and Windows are either registered trademarks or trademarks of Microsoft Corporation in the United States and/or other countries.

* Prices are including VAT and are correct at the time of printing, but subject to change.

/PCSPECIALIST @PCSPECIALIST

PCSPECIALIST

CUSTOM GAMING DESKTOPS & LAPTOPS

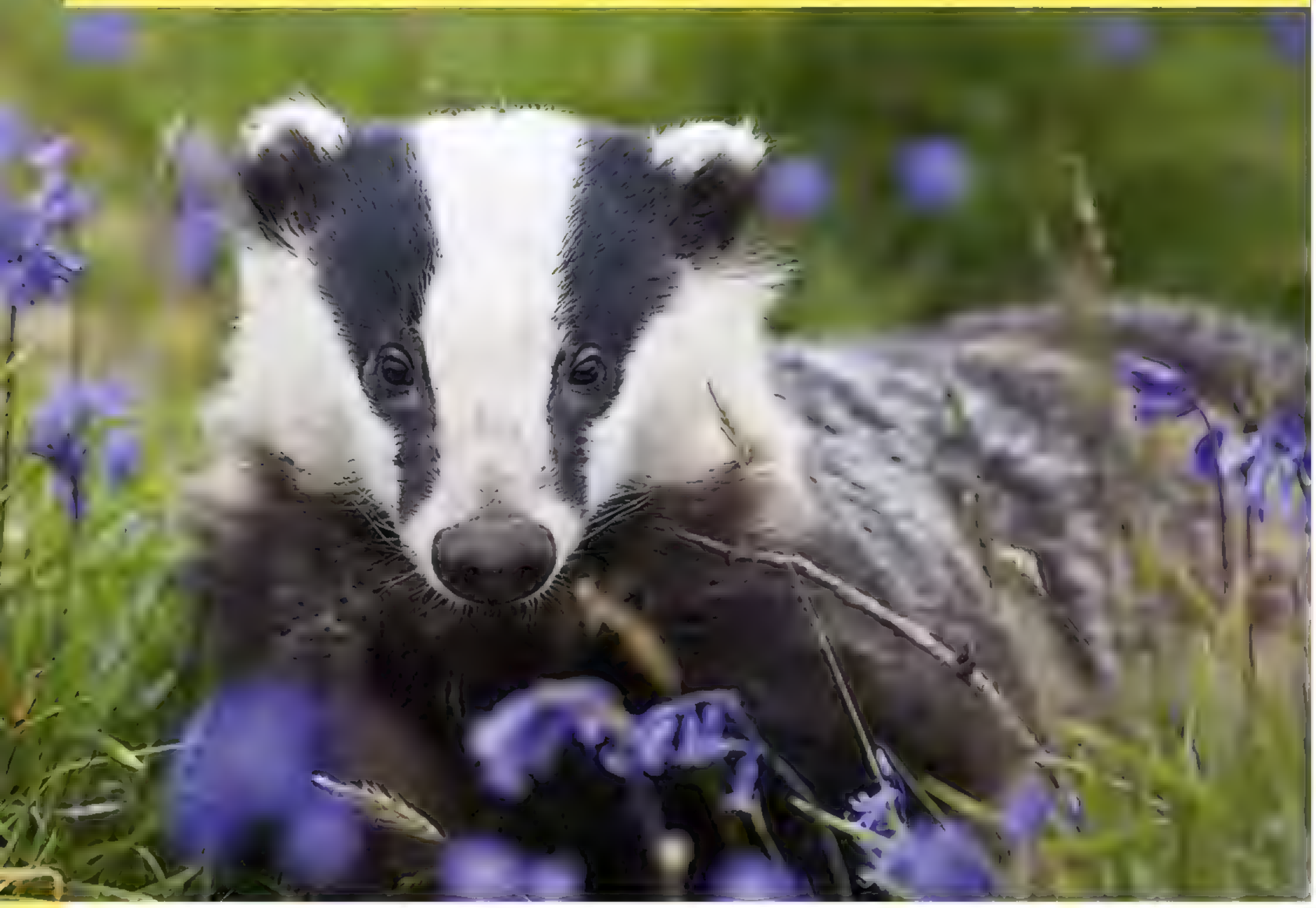
ORDER ONLINE NOW AT

WWW.PCSPECIALIST.CO.UK

REALITY CHECK

SCIENCE BEHIND THE HEADLINES

Badger culls | Food supplements | Antidepressants



REVIEW

BADGER CULLS: DO THEY STOP THE SPREAD OF TUBERCULOSIS?

A recent paper from Imperial College London and the Zoological Society London (ZSL) shows culls drive badgers to roam further, potentially spreading diseases wider. But a Defra-funded study from the same uni suggests culls reduce incidence of tuberculosis by 66 per cent. So are culls effective?

"Maybe badgers are more obviously present than deer, which might make them seem more of a target. A lot more research needs to look at deer"

BBC *Visit the BBC's Reality Check website at bit.ly/reality_check_ or follow them on Twitter @BBCRealityCheck*

WHAT IS BOVINE TUBERCULOSIS?

It's effectively a distant cousin of the bacterium that causes tuberculosis (TB) in humans. Bovine tuberculosis (bTB), or *Mycobacterium bovis*, is a disease that affects farm animals such as cattle and pigs, and wild mammals like badgers, foxes and deer. An infected animal may go undetected for months, but ultimately the disease is fatal. Cattle herds are tested for bTB in an attempt to stop the spread. In 2018, 7.7 million of the 9.6 million cows in the UK were tested, and nearly 45,000 were euthanised due to a tuberculosis-related incident to avoid further infections within the herd.

The Department for Environment, Food and Rural Affairs (Defra) published a policy paper back in 2014 announcing its aim for England to achieve 'Officially Bovine Tuberculosis Free' status by 2038. Objectives include reducing transmission between herds, but also between cattle and badgers. "The strategy will simply not work without addressing the reservoir of TB infection in badgers," the paper reads.

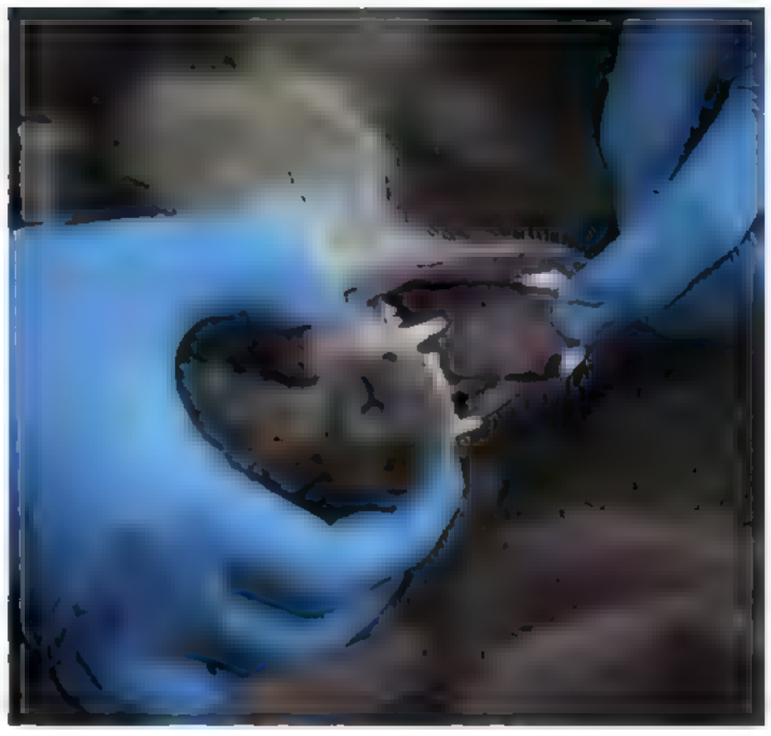
HOW DOES IT SPREAD?

The disease is transmitted either by ingestion or inhalation. *M. bovis* can jump the species barrier, from badger to cattle to human – though cases in people are rare in this country, as pasteurisation kills the bacteria in milk from an infected cow, and meat is inspected before being sold.

Where badgers are concerned, a 2016 study showed cattle and badgers rarely have direct contact. "It's more likely to be indirect, perhaps through infected badger excretion on a cow field," says Cally Ham, PhD researcher at ZSL's Institute of Zoology and Imperial College London, and the lead author on a new study on the impacts of badger culls. However, this method of transmission has yet to be proven.

WHY ARE BADGERS GETTING THE BLAME?

Badgers aren't the only bTB-carrying animals to come into contact with cows. Ham says deer populations also share pasture with cattle, and they can have high levels of infection. "Maybe badgers are more obviously present than deer, which might make them seem more of a target," she suggests. "A lot more research needs to look at deer."



LEFT Badger undergoing health checks

SETH, ACKSON X2

Badgers were identified as carriers of the disease in 1917 and the Badgers Act of 1973 allowed for licences to be given to farmers to kill badgers on their land. But it wasn't until 1997 that a large-scale, scientific review of badger culling was completed. Known as the Krebs Report, the 1997 paper concluded that there was a lack of evidence to support, or discredit, the use of badger culling to control bTB spread. What followed was the Randomised Badger Culling Trials (RBCT), where 11,000 badgers were caught and killed between 1998 and 2005. Two years after the RBCT ended, Defra concluded that "badger culling cannot meaningfully contribute to the future control of cattle TB in Britain."

Then, in 2013, it was announced that pilot badger culls would be implemented first in Gloucestershire and Somerset, and later in Dorset. This came after a steady rise in the number of cows infected with tuberculosis, and a request from the National Farmer's Union (NFU) to the government. The pilots hoped to investigate whether disruption to badger populations would increase the distance that individual badgers travelled, called the 'perturbation effect'. This effect was suggested in the Krebs Report, where further roaming could lead to wider spread of bovine tuberculosis – the exact opposite of the cull's intentions.

WHAT DID THE PILOTS SHOW?

A study of the pilots, led by Sara Downs from the Animal and Plant Health Agency and funded by Defra, found no evidence of the perturbation effect. Tuberculosis incidence rates in Gloucestershire and Somerset were lower than in comparison zones, and there was no difference in Dorset. Downs's paper cautiously suggests that industry-led culling was associated with reductions in bTB. However, it ends by saying: "Culling badgers will not provide the entire solution to the cattle TB problem in Great Britain and the impact of the policy needs to be evaluated alongside other TB controls."

But Ham's ZSL-Imperial study tells a different story. "We fitted GPS collars to badgers inside a government-led cull area and in three unculled areas, to record where they went before, during and after the cull," explains Ham. "Individual ranging behaviour increased with every measure that we tested. There was a 20-fold increase in the odds of a badger trespassing into a neighbouring territory, which has implications for tuberculosis transmission between badgers and between badgers and cattle." It was previously known that badger roaming increases after a cull, but Ham's research has shown they range further during the cull too.

WHAT COULD BE DONE INSTEAD?

"What's missing [from our current understanding] is a properly funded trial of badger vaccination and how that might impact bTB prevalence," says Ham. "We know that vaccination doesn't have the same perturbation effect as culling, but it's not been fully investigated how it might impact cattle infection."

Ham believes the public response to vaccination is better than for culling. But it is the farmers, as the current advocates for culls, who need to be won over. Things are changing, says Ham, who is part of a campaign to help farmers vaccinate badgers on their land.

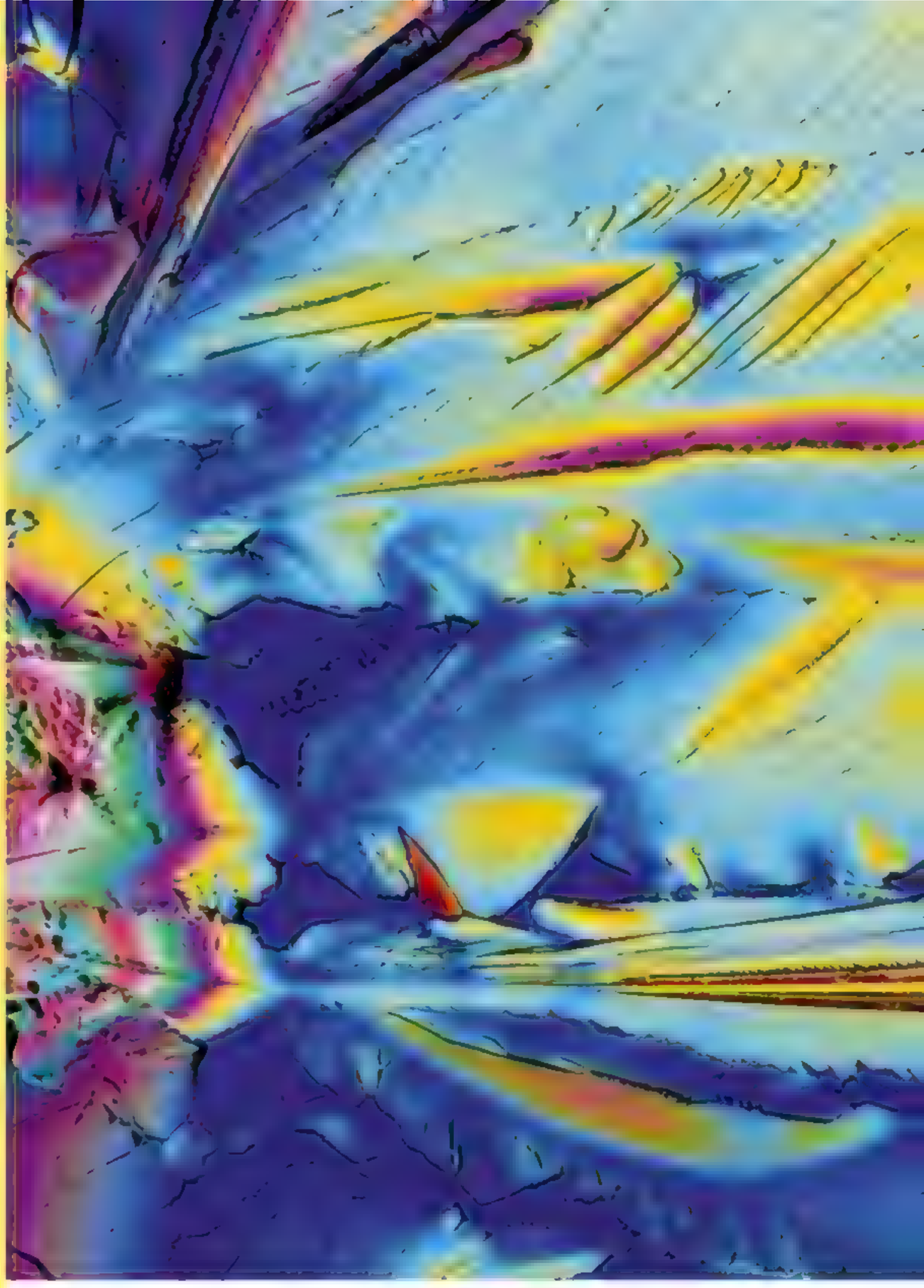
The next step is to further develop vaccinations for cattle. There is currently no test that can determine whether a cow is vaccinated against bTB or infected with the disease, and as such vaccines are prohibited in the UK. Until a test is ready for widespread use, badger populations are still under threat.

by **AMY BARRETT**

Amy is editorial assistant at BBC Science Focus

DISCOVER MORE

For more stories like this, visit our website at ***sciencefocus.com/realitycheck***



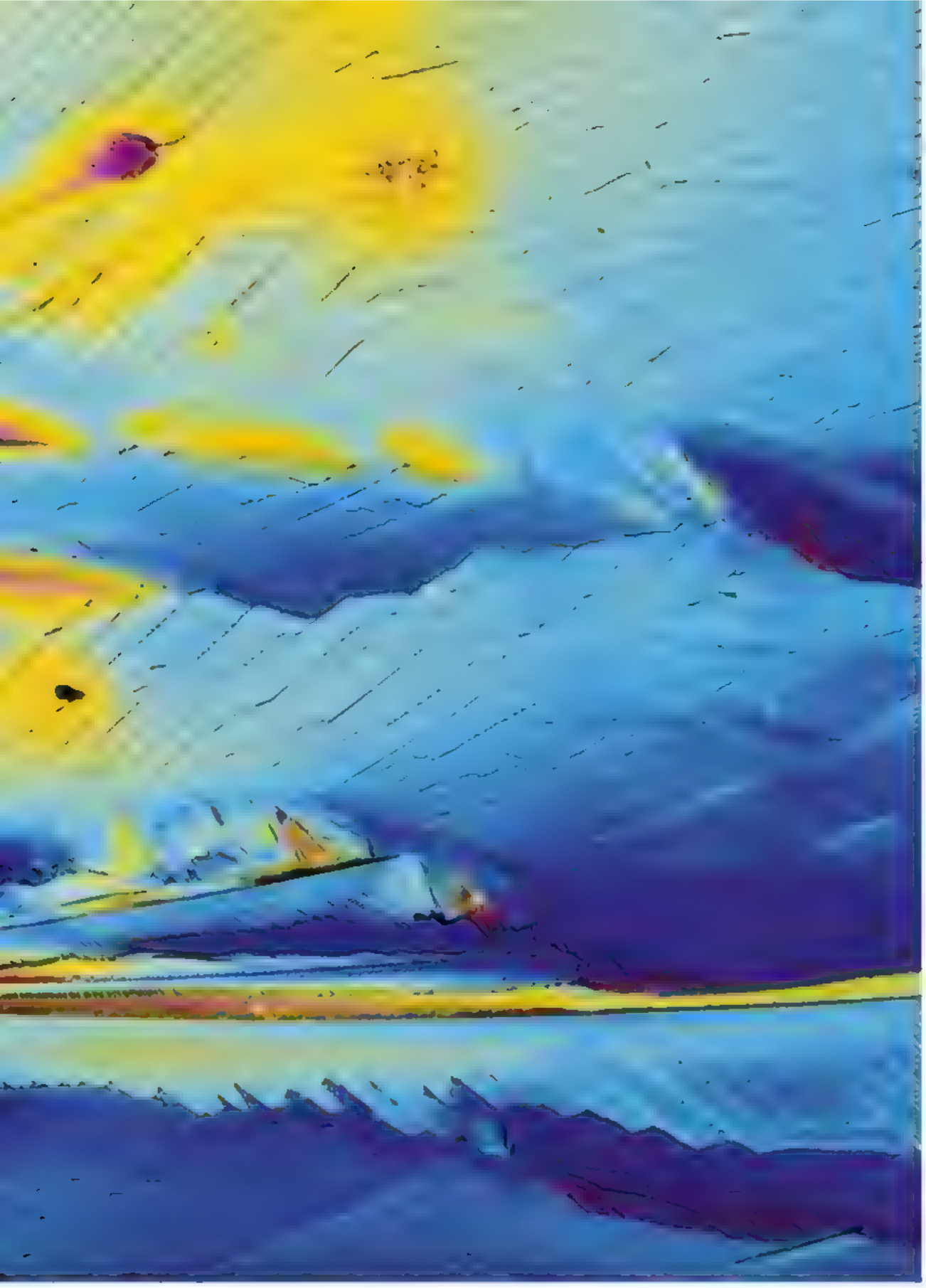
ANALYSIS

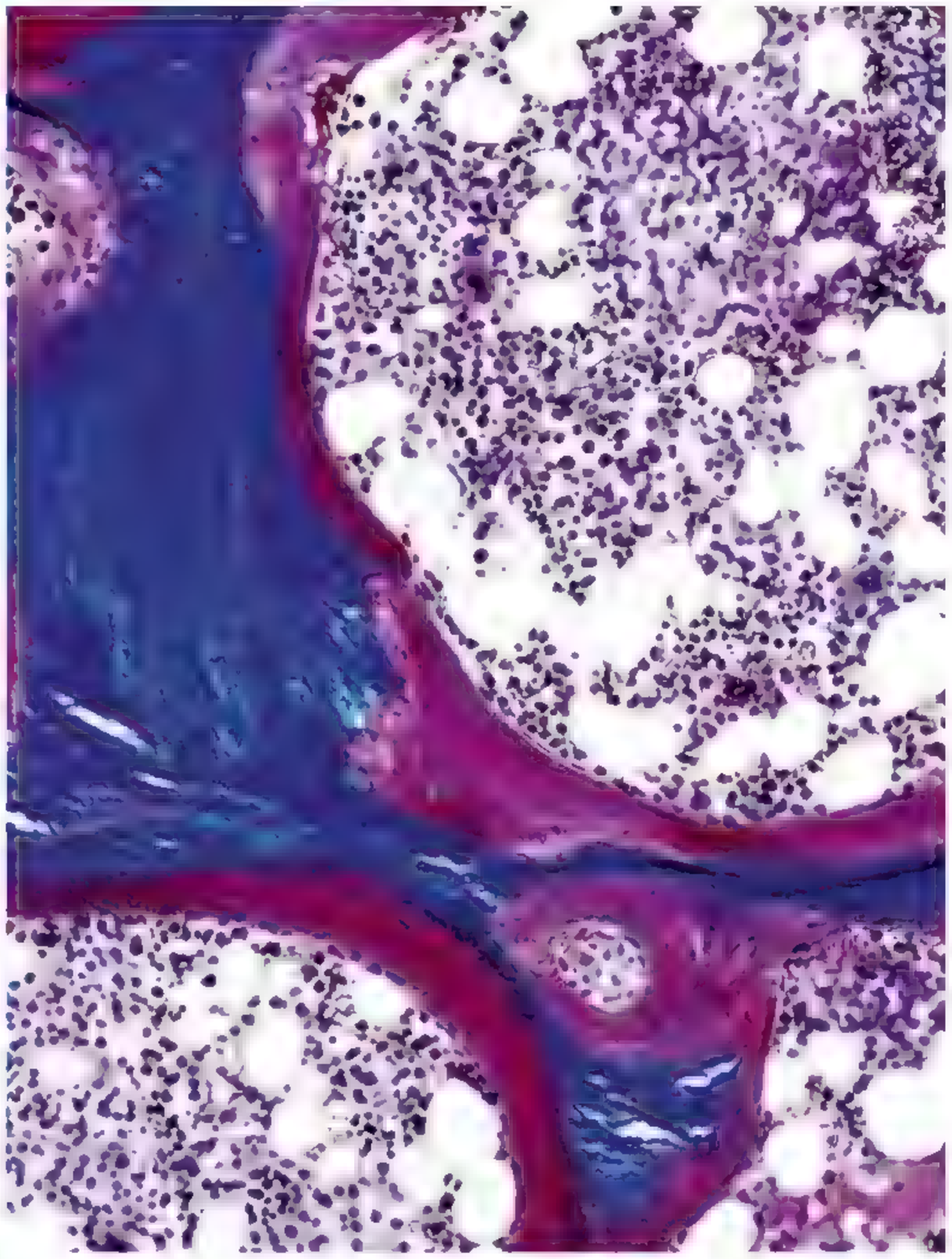
FOOD SUPPLEMENTS: SHOULD WE ALL BE POPPING VITAMIN PILLS?

Many of us take supplements, particularly in winter, as we believe they'll help boost health and wellbeing, and stave off colds. But do they work?

Vitamins and food supplements are big business in the UK, with the market valued at £414m in 2015. A 2018 survey by the Food Standards Agency found that 48 per cent of adults in the UK reported they were currently taking supplements on a regular basis, and in the US, the number is as high as 77 per cent.

So, are all these supplements making us much healthier? A review from 2018 found no conclusive evidence that





ABOVE Crystals of vitamin D, which the body produces when sunlight hits the skin

ABOVE RIGHT A microscope image through a piece of bone tissue that has become weakened due to osteomalacia

taking multivitamins or supplements reduced the risk of mortality from cardiovascular disease or cancer. Some, such as vitamin B3 and antioxidants, might even increase the risk. "A supplement is unlikely to provide you with extra energy or vitality unless you have a deficiency in in some kind of nutrient," explains Dr Gail Rees, a senior lecturer in human nutrition at the University of Plymouth. Despite this, there is one supplement the NHS recommends that everyone in the UK should consider during the winter: vitamin D.

WHAT DOES VITAMIN D DO?

The group of molecules collectively known as vitamin D serve several different purposes in the body. The most important of which is regulating levels of calcium in the blood as well as how much the body absorbs from food.

In the summer, the body produces most of the vitamin D it needs getting the energy the reaction needs from UV light hitting the skin, with smaller amounts absorbed from foods such as red meat, cheese, oily fish and egg yolks. However, in the winter months, most Brits see little sunlight and their levels of vitamin D can drop significantly. By the end of the winter, up to 40 per cent of adults in the UK are deficient in vitamin D, particularly those with darker skin.

Deficiency in vitamin D causes a condition known as osteomalacia (literally meaning 'bone softness') when it affects adults, or rickets in children. Here, the bones gradually soften as calcium leaks out in an attempt to counteract low levels in the blood. "That can cause muscle pain and joint pain," Rees adds. "They could easily fracture and suchlike." So, while vitamin D supplements won't have much impact on the length of your life, they could improve your quality of life by protecting you from aches and pains.

Taking supplements isn't without risk, however. Extremely high levels of vitamin D in the body, in combination with high levels of calcium, can result in a condition known as hypercalcaemia, where calcium starts to build up in the blood. Some vitamins, like vitamin C, are water-soluble, meaning the body can only absorb so much and any excess is flushed out of the body in urine. Vitamin D, however, is fat-soluble, so it can't be expelled when the body has too much. However, the risk of hypercalcaemia is low, Rees says, as long as you follow the instructions correctly. "I would say it's unlikely if you're taking at the recommended

SCIENCE PHOTO LIBRARY X2

"If you have enough vitamins and minerals from your diet, there is no evidence that taking more will prevent you catching an infectious disease"

levels," she says. "So, on the packet, it should say an RDA, or a recommended daily amount. I wouldn't take a supplement that goes over that amount."

WHY TAKE SUPPLEMENTS?

While it's true that supplements won't help you live longer, most people tend to take vitamins and minerals for the more nebulous wellbeing effects they offer, such as extra vitality, more energy and a strengthened immune system. "If you are deficient in iron and are suffering from anaemia, then taking an iron supplement certainly will give you more energy, as iron is involved in carrying oxygen in the red blood cells," explains Rees. So, in that sense, taking supplements can stop you from feeling lethargic, a common side effect of iron deficiency. But vitamins can't give you energy directly: their purpose is to help the body process the energy from carbohydrates, fats and proteins.

Vitamins also can't prevent you from catching winter illnesses like colds and flu. "If you have enough vitamins and minerals from your diet, there is no evidence that taking more will prevent you catching an infectious disease," says Rees. However, if you've already got a cold, taking vitamin C and zinc could do you good: both have been shown to reduce the duration of colds.

Unfortunately, you can't use food supplements to make up for an unhealthy diet. "You could replace the vitamins and minerals that you're missing in your diet by taking a supplement," says Rees. "So, that would stop you becoming deficient in any of those vitamins or minerals, but there's no evidence that doing that would reduce your risk of chronic disease." The main problem with a diet full of processed foods and low on vegetables isn't the vitamins and minerals as such, but the lack of disease-preventing compounds found in plant foods and the high levels of the nutrients known to cause disease: salt, sugar and fat.

So, should we be taking vitamin D over the winter? Rees says there are three key nutrients we should consider supplementing, regardless of whether we have been diagnosed with a deficiency. First, anyone who expects they might become pregnant should take 400 micrograms of folic acid. "Even women who are not pregnant, or not specifically trying for a baby, it may be useful for them to have the recommended amount of folic acid for pre-conception, just in case they did become pregnant," she says. Those following a vegan diet should also consider taking vitamin B12. "It's only really available in animal foods, so meat, chicken, fish and dairy foods, apart from foods that have it fortified." Finally, Rees says yes, she would recommend everyone to consider taking vitamin D through the winter. "We're not saying that people are necessarily going to get rickets or deficiency diseases, but we do know that during winter, vitamin D levels drop really low."

by **SARA RIGBY**
Sara is the online assistant at BBC Science Focus

ABOVE You can't use food supplements to make up for an unhealthy diet

GETTY IMAGES

COMMENT

ANTIDEPRESSANTS: WHY DO PEOPLE THINK THEY'RE INEFFECTIVE?

News coverage of antidepressants often claims that they have little impact on mental illness. So why are they prescribed at all?

Antidepressants are one of the most commonly prescribed drugs in today's world, and according to NHS figures, their use is on the rise. However, counterintuitive as it may seem, you regularly see reports and stories insisting that antidepressants are of little to no effectiveness. How can this be? How can one of the most common (and tightly regulated) types of medication be regarded as being of no use? It's because the reality of antidepressants is far more complex than most seem to think.

First, there are many types of antidepressants. The most commonly prescribed are selective serotonin reuptake inhibitors (SSRIs) such as Citalopram and Prozac, but there are many kinds available, like tricyclic amines, monoamine oxidase inhibitors, and so on. While the goal of each is the same (treating depression), they have notably different mechanisms of action, interfering with different neurons, altering the levels of different neurotransmitters and so on.

It's entirely possible for someone to experience no benefit from a certain type of antidepressant, but that doesn't mean none of them can, or will, work. Similarly, there are many types of depression. The most familiar is probably major depressive disorder, but there is also postpartum depression, dysthymia, seasonal affective disorder, psychotic depression, catatonic depression, and more. The systems via which our brains produce, control and regulate our mood are complex and still not completely understood, but it's virtually certain that there a number of ways for depression to occur. Sometimes, dealing with it is a matter of matching the right antidepressant to the right depression.

"They're not supposed to 'cure' the depression. Psychiatric medications are about reducing symptoms"

NOT YOUR AVERAGE PILL

Like all medicines, antidepressants have a wide range of unwanted potential side effects. Accordingly, it's not just effectiveness that clinicians must consider, but tolerability. Can a typical patient put up with the negative effects of the medication, and still experience the benefits? It's a fine balance that requires expert oversight and monitoring to get right.

Interestingly, SSRIs are the most common antidepressants, but not because they're the most effective. If anything, studies have shown they have perhaps the weakest therapeutic effects on depression, leading to news reports that they do little to relieve depression symptoms. But they also seem to have the mildest side effects, so new patients are much less likely to react badly to them. But it also means the odds of genuine depression relief are reduced. If SSRIs prove ineffective, another type can be tried. It's often a matter of trial and error until an effective type is found. Every brain is different and there are many forms of depression, after all. And some forms of depression are hard to tackle with medication, giving rise to treatment-resistant depression.

Finally, psychiatric medication doesn't work like more typical medication. Most people think of medication as something that 'fixes' the problem. If an antibiotic didn't clear an infection, or if a painkiller didn't get rid of your pain, you'd reasonably assume they 'don't work'. But the same rules don't apply for antidepressants and other psychoactive medications. They're not supposed to 'fix' or 'cure' the depression (although it'd be nice if they did). Psychiatric medications are more about reducing symptoms, or restoring some sort of functionality or control over your mental state.

Mental healthcare overall is rarely about curing or fixing, because such things are usually beyond our understanding at present. It's more about managing, adapting, lessening, and so on. If you consider antidepressants in this context, it's easier to see how they could 'work'. But if you insist on thinking of them in terms of more 'typical' medication, then it will seem like they don't.

—

by **DEAN BURNETT**

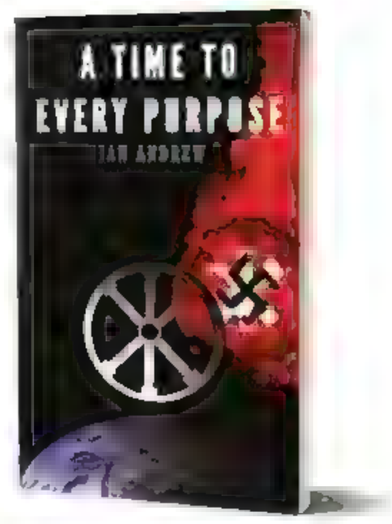
Neuroscientist Dean discusses all this and more in his new mental health audiobook Psycho-Logical, *an Audible exclusive*

A Field Guide to the Moon
Wildsam
wildsam.co.uk

For all of human history, the Moon has captured the world's imagination. In this tribute volume, Wildsam explores the shared wonder of our celestial neighbor via archival storytelling, astronomical insight, essays, interviews and more.

STORIES, INTEL AND LORE, INCLUDING:

The History of Rocket Technology
Apollo Astronauts of Renown
A Short History of Lunar Photography
Presidential Aspirations and the Space Race
The Moon in Literature, Music and Film
Personal Memories of Apollo 11
An Interview with Mission Control

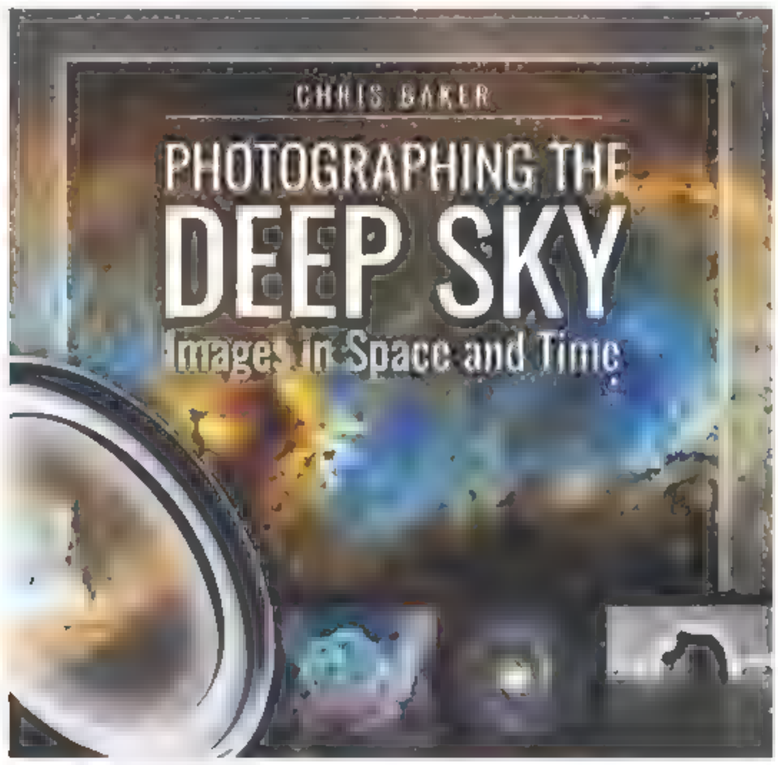


A Time To Every Purpose
Ian Andrew
bookreality.com
RRP: £14.99

In a world where Jesus was never crucified, religions have all but been eradicated and the Greater German Reich is in global power.

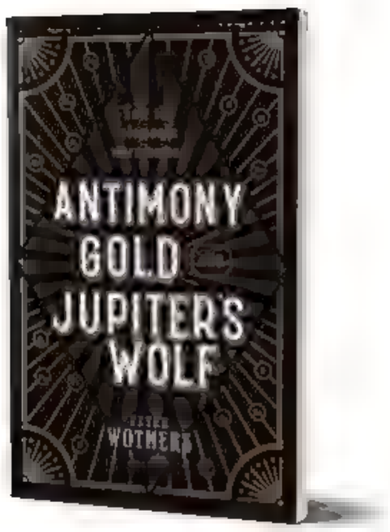
'It's a telescope that looks back in time.'
'All telescopes do that.'
'True. But this one looks back at the earth. Anywhere, at any point in history. In real time.'

Now, Leigh Wilson, one of the leading scientists of her generation has a problem. Her discovery is wanted by the SS.



Photographing the Deep Sky
Chris Baker
pen-and-sword.co.uk
RRP: £25.00

Spectacular nebulae where stars are born, beautiful star clusters from the early formation of the Milky Way, and galaxies as far as a billion light years away, all feature in this book of stunning images. The images are of objects from hundreds to many millions of light years away. The book presents fascinating information on what the Earth was like when the light started its earth-bound journey through space. With a concise, clear discussion on the background of astronomical science, this is a book to celebrate the beauty and fascination of space.



Antimony, Gold, and Jupiter's Wolf

How the elements were named

Peter Wothers

global.oup.com/academic/

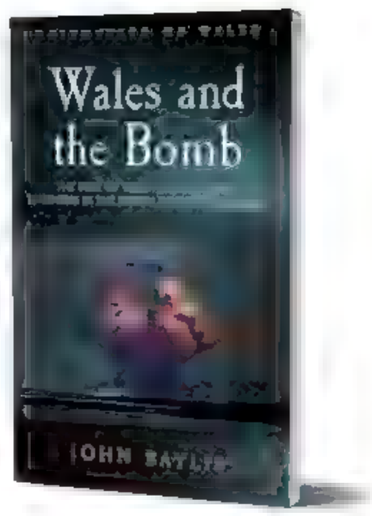
The Periodic Table is now in its most satisfyingly elegant form, as its 'gaps' have been filled and the corresponding elements named. But where do these names come from? Here, Peter Wothers explores the fascinating and often surprising stories behind the names of chemical elements; while some were controversial, they have nonetheless influenced language to this very day. Wothers delights in dusting off original sources and bringing to light these astonishing, unusual, and downright weird elemental origin stories.

Energy, the Great Driver

R. Gareth Wyn Jones

uwp.co.uk/book/energy-the-great-driver-paperback/

This book explores the relationships between energy, work, power and material and social complexity suggesting that in six revolutions this relationship has been fundamental to the trajectory of life on our planet. The stability of this growing complexity has required a parallel hierarchy of homeostatic, regulatory mechanisms, and the profoundly disturbing implications of these twin hypotheses to the challenges of anthropogenic climate change are explored.

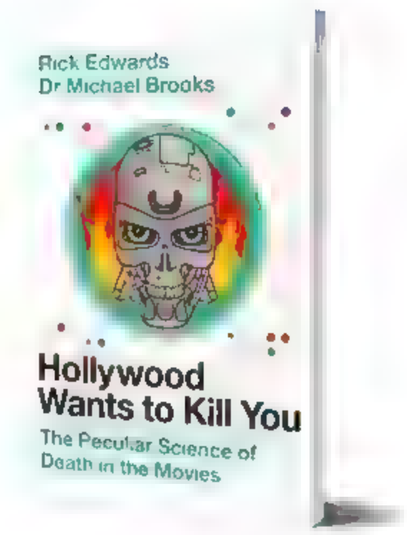


Wales and the Bomb

John Baylis

uwp.co.uk/book/wales-and-the-bomb-paperback/

Nuclear weapons pose very difficult ethical, scientific, engineering and industrial problems. Given the continuing contemporary debate about the utility or otherwise of nuclear weapons, it is instructive to look back at the evolution of the British nuclear programme, a fascinating story in which Wales and some of its leading scientists and engineers played a significant role in developing atomic and later thermonuclear weapons.



Hollywood Wants To Kill You

Rick Edwards and Michael Brooks

amazon.co.uk/dp/1786496925

RRP:£12.99

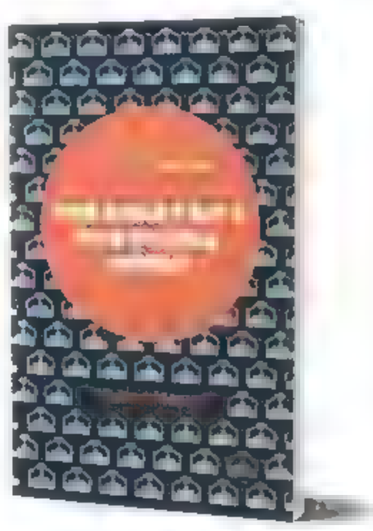
Asteroids, killer sharks, nuclear bombs, viruses, deadly robots, climate change, the apocalypse - why is Hollywood so obsessed with death and the end of the world? And how seriously should we take the dystopian visions of our favourite films? Packed with illustrations, fascinating facts and numerous spoilers, *Hollywood Wants to Kill You* explores the science of death and mass destruction through some of our best-loved blockbusters, from *Armageddon* and *Dr Strangelove* to *The Terminator* and *Contagion*.

Smart Cities: Introducing Digital Innovation to Cities

Oliver Gassmann, Jonas Böhm & Maximilian Palmié

bit.ly/smartcitiesgassmann

Transformation through digital innovation is becoming imperative for every city. The 'Smart City' concept promises to solve the most urgent queries of progressive urbanization in the area of mobility, energy, water supply, security, housing deprivation, and inclusion. This book identifies and addresses the core elements and potential of smart cities, best practice methods and tools to be implemented, as well as how diverse stakeholders might be effectively integrated.

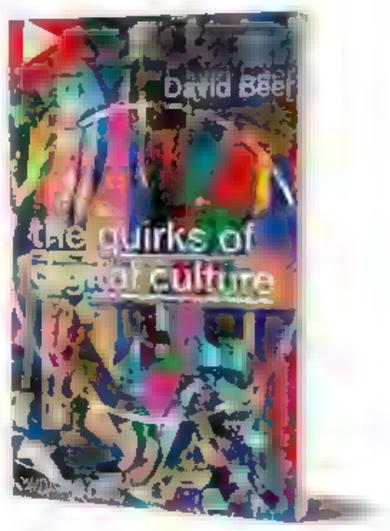


The Smart City in a Digital World

Vincent Mosco

bit.ly/moscosmartcity

The Smart City in a Digital World insists that people make cities smart, that human governance matters, and that intelligent cities start with vibrant democracy, commitment to public space, and to citizen control over technology. To make this happen, we need to understand the technologies, organizations, and mythologies that power this movement, as well as resistance to technology-driven cities. Exploring case studies around the world, this book is an essential guide to the future of urban life in a digital world.



The Quirks of Digital Culture

David Beer

bit.ly/quirksdigitalculture

Offering a way of understanding the chaos and messiness of on-demand culture, David Beer focusses on some of its 'quirks' and uses these as openings to see inside patterns and dynamics of new cultural formations. This book is a guide to understanding the complex and unsettling cultural present, whilst also making some predictions as to what may unfold in the future.

The Human DNA Manual

Dr Melita Irving

haynes.com/human-dna-manual

The Haynes Human DNA Manual aims to enlighten the reader on all aspects of our genetic code. Dr Melita Irving's book brings together all the fascinating strands of genetic science and explains in an accessible way how DNA is being mapped, classified, utilised and understood. With sections on ancestry, evolution, sequencing the human genome, genetic disorders, gene editing, and epigenetics, this book shows how outstanding breakthroughs in archaeology and science are informing us about our past, and defining our future.

SFP344

BBC

Science Focus MAGAZINE

SUBSCRIPTION ORDER FORM

Please complete the order form and send to:
FREEPOST IMMEDIATE MEDIA *(please write in capitals)*

UK DIRECT DEBIT

☐ Yes, I would like to subscribe to/renew *BBC Science Focus* paying £34.99 every 14 issues – saving 50% *

YOUR DETAILS (ESSENTIAL)**

Title _____ Forename _____

Surname _____

Address _____

_____

_____ Postcode _____

Home phone no _____

Mobile phone no** _____

Email** _____

☐ **I wish to purchase a gift subscription**

GIFT RECIPIENT'S DETAILS (ESSENTIAL)**

Title _____ Forename _____ Surname _____

Address _____

Postcode _____ Home phone no _____

Mobile phone no** _____

Email** _____

Instructions to your bank or building society to pay by Direct Debit

To: the Manager (bank/building society)

Address

Postcode

Name(s) of account holder(s)

Bank/building society account number **Branch sort code**

Reference number (internal use only)

Originator's identification number

7 1 0 6 4 4

Please pay Immediate Media Co Bristol Ltd debits from the account detailed in this instruction subject to the safeguards assured by the Direct Debit Guarantee. I understand that this instruction may remain with Immediate Media Co Bristol Ltd and, if so, details will be passed electronically to my bank/building society.

Signature Date / /

Banks and building societies may not accept Direct Debit mandates from some types of account

KEEP IN TOUCH

***BBC Science Focus Magazine* (published by Immediate Media Company Limited) would like to send you updates, special offers and promotions by email. You can unsubscribe at any time. **Please tick here if you would like to receive these** ☐

We would also like to keep in touch by post and telephone about other relevant offers and promotions from Immediate Media. If you do not wish to be contacted this way please tick here post ☐ phone ☐. For more information about how to change the way we contact you, and how we hold your personal information, please see our privacy policy which can be viewed online at **immediate.co.uk/privacy-policy**

OTHER PAYMENT METHODS

☐ **UK cheque/credit/debit card** – £34.99 for 14 issues, **saving 50%**

☐ **Europe** inc Eire – £73.35 for 14 issues

☐ **Rest of world** – £74.75 for 14 issues

☐ I enclose a cheque made payable to Immediate Media Co Ltd for £ _____

Visa ☐ Mastercard ☐ Maestro ☐

☐☐☐☐ ☐☐☐☐ ☐☐☐☐ ☐☐☐☐ ☐☐☐☐

Issue no ☐☐ Valid from ☐☐☐☐ Expiry date ☐☐☐☐

Signature _____ Date _____

If credit card address is different, please use the order hotline 03330 162 113

OVERSEAS Please complete the order form and send to: *BBC Science Focus Magazine*, PO Box 3320, 3 Queensbridge, Northampton, NN4 7BF

***Offer ends 31 December 2019.** 50% saving is only available to UK residents. Personal subscriptions will start with the next available issue. Gift subscriptions will start with the January issue mailed out after Christmas.

You may photocopy this form

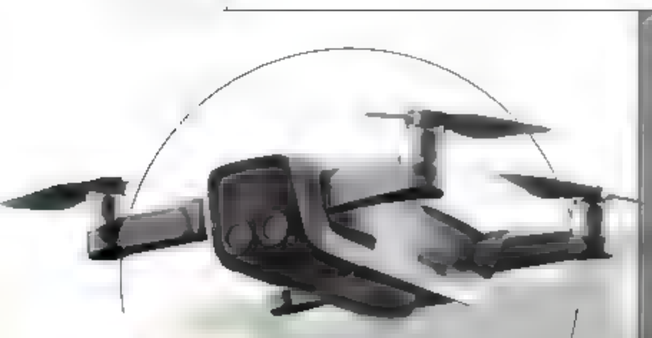
INTRODUCTORY CHRISTMAS SUBSCRIPTION OFFER

50%

WHEN YOU SUBSCRIBE TO *BBC SCIENCE FOCUS MAGAZINE* TODAY*

- Save 50% on an annual subscription
- Pay just £34.99 every 14 issues by Direct Debit, saving 50%!
- Receive every issue delivered direct to your door with FREE UK delivery

Online	Phone	Post
buysubscriptions.com/SFP344	**03330 162 113+** (please quote SFP344)	**FREEPOST IMMEDIATE MEDIA** (please write in capitals)



This pocket-sized drone packs a punch p43

INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

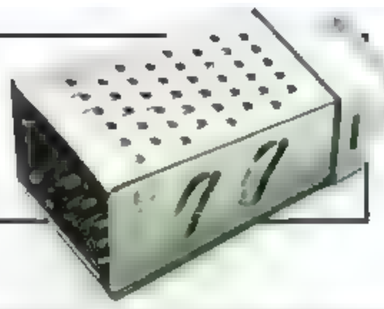
Despite its windows shattering during the launch demo, the Cybertruck has still scooped thousands of pre-orders

CYBERTRUCK ALIKES

→ Big Trak electric toy car

→ *Star Wars* sandcrawler

→ Cheese grater Sorry, Elon



This electric estate car concept from VW shows that spacious cars of the future don't need to be big and bombastic

The icon goes electric. Ford's first electric car will be an SUV variant of the Mustang. Two birds, one stone?

This concept was the best-looking car at the LA Auto Show. Plus, it doesn't look too different Lexus's flagship LFA.

FIRST LOOK

What the truck?!

Tesla's new futuristic design divides opinion

Last month, Elon Musk revealed the latest addition to the Tesla family, a pickup truck. With the company taking 200,000 pre-orders in just 48 hours, it's clear that the Cybertruck is a hit with Tesla's devotees. The sheer volume of orders shocked critics, who thought the haphazard presentation (which saw the armoured glass broken by Musk), and the design would stifle demand. So, we asked the *BBC Science Focus* team's two car lovers, Daniel Bennett and James Cutmore, to duke it out.

DB: Well, I know I'm in the minority. And I'm at risk of ruining my credentials, but I actually think the Cybertruck is, and I'll say it quietly, kind of cool. You could even call it brutalist design...

JC: No way. It looks something one of my kids drew on the kitchen wall. It feels like someone ran out of time on their deadline at the Tesla design studio. The number of pre-orders just tells me that people will buy anything if the right name is attached to it.

DB: Sure, Musk has his fair share of acolytes, but I think the pre-orders are testament to how good Tesla have been at disrupting the car market. Modern cars can be samey, and people love Tesla because they're are so different from the status quo.

JC: Sure, they have disrupted the car market, but are their products really that good? The Cybertruck doesn't even look finished.

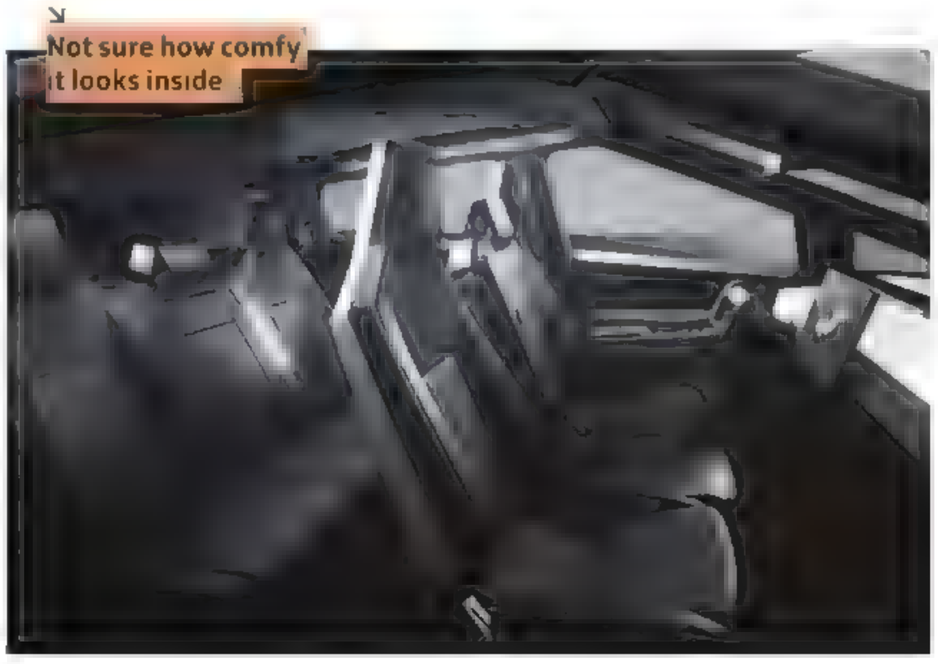
DB: Well the Tesla Model 3 was described as "the safest car ever tested" by the US National Highways Administration, and Tesla often tops independent customer satisfaction surveys, so surely they're getting something right?

JC: I guess you could say the Cybertruck is a brave choice, even if it looks like the kind of cheese grater you'd find in a high street department store, but I do wish manufacturers would stop churning out these huge SUVs that clog up the roads.

DB: There's something we can agree on. At the LA Auto Show, which took place just before the Cybertruck launch, there was a juxtaposition of huge SUVs next to all-electric cars showcasing their brand's green potential. People are buying more SUV-type vehicles than ever, and it seems like, car companies are caught between that and shrinking CO_2 targets from the EU. At least this big car – or truck – is electric...

JC: That is one thing to be thankful for. But I would like to see somebody being brave and making something smaller for the masses. I don't think the roads in Europe can take much more traffic. Maybe someone should try and design a new Sinclair C5...

"YOU COULD SAY THE CYBERTRUCK IS A BRAVE CHOICE, EVEN IF IT LOOKS LIKE A CHEESE GRATER"



ALAMY

THE TEST

A good night's sleep

Getting to sleep and waking up can be tough at this time of year, says Daniel Bennett. And sleep tracking apps and devices won't necessarily solve the matter. So put away the phone, and consider these innovations that have been helping us get some rest

1. Philips Somneo

Long nights and grey skies play havoc with my circadian rhythm. I'm tired in the morning and wired by night. The Somneo has two functions to try to remedy this. In the morning it'll simulate sunrise and at night it'll do a good impression of dusk. The faux-dawn glow works unnervingly well. I'm a reluctant riser, but I felt strangely awake when the alarm started. The bigger surprise was the efficacy of the dusk setting. The slowly dimming light, paired with a book, never failed to weigh down my eyelids within half an hour. A great device, albeit with a big price tag.

philips.co.uk

2. Simba Hybrid Duvet

Being too hot or too cold can be a barrier to sleep, especially if, like me, your partner would probably feel happiest sleeping in an igloo. Inspired by spacesuits that mitigate the temperature difference between a body and space, one side of this duvet is lined with a material that absorbs excess heat and returns it when the temperature drops. It sounds like magic, but in reality it seems to work. Not only could I feel the difference in warmth between my side of the bed and the other half's, but the space between us was almost chilly. Best of all, this means the duvet is just as good in summer as it is winter.

3. Sound Oasis Illumy

Astronauts need their rest too. To help scientists aboard the ISS maintain a regular sleep cycle in the absence of night and day, NASA uses red and blue light to tell the body when it's time to switch on and off. This eye mask takes the idea further, beaming red pulses at you when you're trying to sleep and blue ones in the morning. The mask was too bulky for me, but my partner, who works and sleeps at irregular times of the day, found the rhythmic red light strangely relaxing, and the blue light useful in waking her up. Definitely one for those of us out there who have to sleep in the day and work by night.

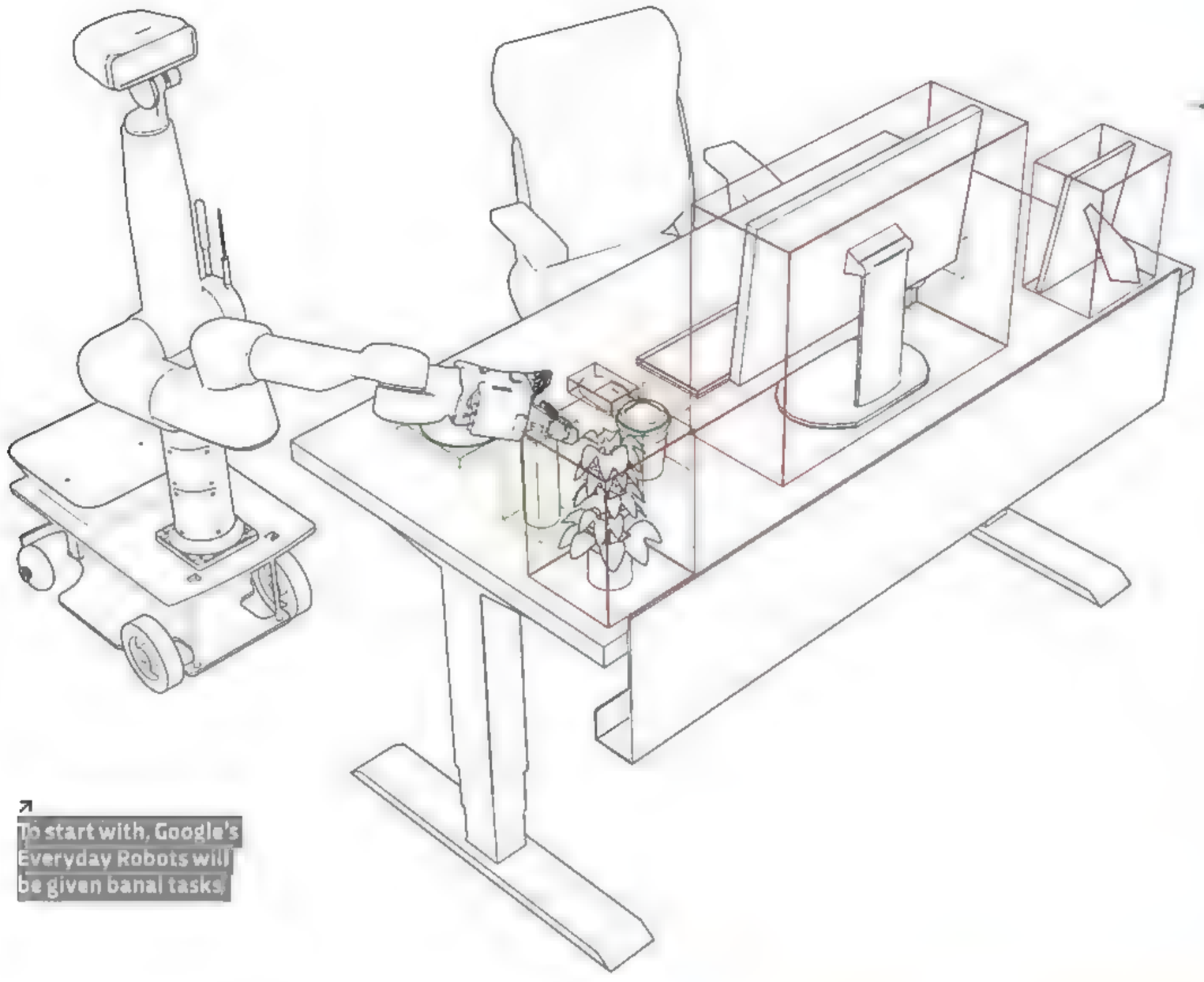
£99.99 (£77) soundoasis.com

4. Flare Sleeeps

I am a light sleeper and live in a one-bedroom flat with a partner who works night shifts, so my sleep is rarely uninterrupted. Most foam earplugs are too large and, by morning, leave my ears feeling irritated. Short of strapping pillows to my head, I've tried everything. Flare – who usually makes high-end earphones – has used its aural knowhow to design these earplugs to help sleepers shut out the world. The memory foam makes them surprisingly comfortable, and they expand slowly once inserted, fitting the shape of my awkward lugholes. They're comfortable and ship in packs of three.

£9.99 flareaudio.com

GETTY IMAGES



To start with, Google's Everyday Robots will be given banal tasks

Where's my robot butler?

Google wants to crack one of the biggest challenges in robotics: a robot that can actually help out with everyday life

Robots have explored Mars, charted the ocean depths and inspected some of the most hazardous sites on Earth, but for some reason, they still can't help us do the washing up. But Google's 'moonshot' division, Alphabet X, hopes their new Everyday Robot project could finally solve this problem, with the help of some machine-learning software. The idea is to create a robo-aide, that, through a sophisticated process of physical and virtual trial and error, can teach itself how to do day-to-day tasks.

Getting a robot to do housework is a tricky task, as there are lots of variables – many of which are hard to predict (I still struggle to get the recycling right). So Alphabet X is starting with a banal, seemingly simple task: getting rid of rubbish in their offices. To succeed, the robot needs to work out how to identify different materials and which bin they belong in. Of course, there are other challenges too, like navigating a bustling office and making sure it doesn't drop or spill anything. To learn, the robot just needs continual feedback on its accuracy. According to Alphabet X, the project has already yielded some success: the robot only misplaces rubbish 5 per cent of the time. The long-term goal is to end up with a robot that can deal with complex, messy human environments that are full of unpredictable tasks. And if they can crack that, they can have all my money.

"THE LONG-TERM GOAL IS TO END UP WITH A ROBOT THAT CAN DEAL WITH COMPLEX, MESSY HUMAN ENVIRONMENTS"

THE DOWNLOAD

DRONE REGISTRATION

Got a drone? Register it.
A new law came into effect in the UK on 30 November. It states that any drone weighing over 250g must be registered online on the Civil Aviation Authority's (CAA) website, before you can fly it. The person registered with the drone must be over 18, and must pay a £9 annual fee. Anyone of any age can still fly a registered drone, but they have to fill out a form online.

One drone disrupted more than 1,000 flights.
The law has been introduced because a drone flew into Gatwick's airspace over a series of days in 2018. Planes were grounded, and the disruptions are reported to have affected 140,000 passengers and cost millions of pounds.

There are 130,000 drone users in the UK, according to the CAA.
At time of writing, around 50,000 people had registered. Anyone caught flying negligently (flying low, around people) or flying an unregistered drone will face hefty fines, and potentially crimina. charges, according to the police.

Drone manufacturers are doing their bit.
Tech companies now install most drones with GPS geofences that block the drone from entering restricted airspace. DJI, the largest drone seller in the world, recently demonstrated an app that will allow phones to identify a flying drone, and its pilot's location.

Ideas we like...

1.

Alienware m17

Gaming laptops of yore stretched the definition of portable, but it looks like high-end PCs are growing up a bit with this year's Alienware m17. It's thinner, lighter and slicker than its predecessors, with less of the geeky styling. Powering the m17 line-up of laptops is Nvidia's RTX 20-series graphics card, which allows for ray-tracing, a graphical trick which lets games better simulate how light falls on objects. Basically, it means it's as futureproof as a PC laptop can be.

← 2.

OnePlus 7 Pro

This year, there have been new Android smartphones from Google, Samsung, et al. But it's the OnePlus phone that we'd want in our pocket. One of the fastest processors in the business powers a screen with a 90Hz refresh rate, making the phone and all its apps feel magically slick. There are some foibles, like no wireless charging or headphone sockets, but it's also much, much cheaper than its competitors.

^ 3.

Motorola Razr

While we haven't actually got our hands on the new Razr, we can't help but yearn for this modern take on a classic design. We're hoping the folding screen is tough enough to handle the unreasonable number of times we're going to open and close it. Either way, whoever can crack (no pun intended) a folding phone that doesn't break in day-to-day use will probably make a lot of money in 2020.

Sony WH-1000XM3

These are some of the best wireless headphones we've ever used. We could go on about the fast-charging – which can give you five hours of extra life in 10 minutes – or the noise-cancelling that's particularly good at wiping out mid and treble tones produced by a noisy office. But we just like the sound provided by a built-in DAC and analogue amplifier that produces a warm, roomy experience that feels like it's opening up your music.

6. ↑

Oculus Quest VR

Depending on who you ask, the public's interest in VR is either waning or booming. For us, it's a niche interest, but it's still a pursuit that we get excited about. If you want to leave the pesky physical world behind, there's probably no better way to do so than the Oculus Quest. It doesn't require an expensive PC, a big room, or a tangle of sensors – everything you need is in the headset and its controllers. Oculus is adding hand and finger tracking to the headset's capabilities next year too.

7. ↓

Naim Mu-so 2nd Generation

Naim has re-engineered its all-in-one speaker while leaving the design intact. The streaming tech has been upgraded to boost fidelity when you're listening to music, while the signal processor now handles 2,000 MIPS (million instructions per second), compared to the original's 150 MIPs, to eke more out of your music files. Plus, it now has HDMI ARC compatibility for buyers who want to use it with their TV. And there's an entirely new speaker setup inside.

5. →

Nintendo Switch Lite

The only thing that's not to like about a Nintendo Switch is its price, so this cheaper, smaller, handheld version is a no-brainer, so long as you can live without the option of hooking it up to your TV. This is handheld gaming at its peak.

DJI Mavic Mini

This tiny drone fits in your coat pocket, and at 249g is a fair bit lighter than a can of pop. Its featherweight design means the Mavic Mini skirts US and UK law that requires anything weighing over 250g to be registered with local aviation authorities. To come in at that size, there's no 4K video on offer or object tracking, but you still can deliver fluid, stable 60fps footage at 1080p resolution.

HOW TO GROW FOOD IN SPACE

AT A REMOTE OUTPOST IN ANTARCTICA, SCIENTISTS ARE GROWING VEGETABLES

WORDS: HAYLEY BENNETT PHOTOGRAPHY: ESTHER HORVATH

Today's astronauts have to exist largely on pre-packed meals, with fresh fruit and veg being a rare treat. But indoor farming technologies are advancing, and the race is on to find effective ways to grow food in space – both for long-duration missions, and for future settlements on the Moon or Mars. So where's the best place to test these technologies? The bottom of the world, it turns out. At the Alfred Wegener Institute's Neumayer III station in Antarctica – a German base for polar research – scientists have created a standalone greenhouse as part of a project called EDEN ISS, which develops food production techniques for the International Space Station (ISS) and future human space colonies. Here, researchers are already seeing the fruits, or at least vegetables, of their labour.

FROZEN VEG

The frozen landscape of Antarctica might seem an unlikely place for a greenhouse, but the isolation, limited resources and harsh environment make it an ideal analogue of the conditions faced by astronauts growing crops in space. The 12-metre-long mobile facility – made from two interconnected shipping containers – houses soilless technology for indoor farming, including temperature and humidity control systems, water recycling, automated nutrient pumping, LED lighting and remote plant monitoring. It was kitted out in Germany and shipped to Antarctica in October 2017.

In this picture, EDEN ISS leader Dr Daniel Schubert (right) and a colleague drag a sledge loaded with supplies to the greenhouse facility, which is about 400 metres from the main Neumayer III station. It's "a pain in the ass" to get to in these conditions, Schubert says, explaining that the greenhouse is positioned this far away because of the huge snowhills that form behind any large object. The main station itself avoids this problem because it is specially shaped and raised on hydraulic stilts to prevent snow from accumulating.

↑ →

PUTTING DOWN ROOTS

The cultivation process at EDEN ISS is aeroponic – a soilless system where the crops absorb nutrients from a water mist applied at the roots. The vegetables are grown in vertical racks, giving a total growing area in the greenhouse of 12.5 square metres, with the roots exposed in plant growth trays.

Everything in the greenhouse can be regulated remotely from mission control at the German Aerospace Centre in Bremen, except, notes Schubert, seeding, harvesting and cleaning up – these have to be done by hand. Here, horticultural engineer Markus Dorn (right) prepares the seed trays using blocks of rock wool soaked in nutrient solution. Rock wool, which is made by spinning molten rock into fibre, has a candy floss-like texture that holds onto water and helps stabilise roots. The seeds will germinate in the seed trays for about two weeks before being transferred to the vertical racks.

↑

UNDER SURVEILLANCE

The greenhouse features a crop surveillance system: high-definition cameras that help the team keep tabs on the plant growth trays. In this image, plant scientist Dr Anna-Lisa Paul from the University of Florida is calibrating a specially adapted camera that is capable of detecting crop stress – in kohlrabi, in this case – even before it's visible to the eye. (The colour plate helps to make sure the colours are aligned between different images.) Healthy, unstressed plants that are well-hydrated and have all the right nutrients reflect a higher ratio of light in the 'near-infrared' part of the spectrum compared to shorter wavelength blue and green light. The camera is able to detect these wavelengths, determining whether the plants are stressed or healthy. Paul says that this means problems can be addressed before they become irrecoverable. "This is especially important when resources are limited, and the habitat is inherently challenging, such as in space," she says.

→

REAP WHAT YOU SOW

Over the 2018 Antarctic winter, between February and November, the greenhouse produced 268 kilograms of crops, including 67 kilograms of cucumbers and 50 kilograms of tomatoes. The impressive harvest shown here was collected early the following year, in January 2019. In addition to cucumbers and tomatoes, the crew were treated to swiss chard, radishes, fresh herbs and different varieties of lettuce. The LED lighting is tuned to produce mostly red light, as this is the most effective colour for driving photosynthesis, but there are seven different light 'regimes' tailored to the height of the crops and the amount of light they need. "We've developed specific light mixtures for the plants," says Schubert. "So the lettuce, say, receives a different light mix than the cucumbers." The light also scales up slowly in the morning, creating an artificial dawn. Except for tomatoes, no fruit is grown here, but the crew have frozen fruit in their stores.


L1-2R
L2-1L
L2-2L

NASA/SC GETTY MAGES

FRESHLY CUT

With no hair salons for thousands of kilometres, station leader Dr Bernhard Gropp has taken up the clippers, giving electrical engineer Thomas Schad a haircut. Team bonding is important in these extreme conditions – in winter the temperature can fall below -40°C, and the polar night means that for 11 weeks of the year no sunlight touches the ice. As in space, a haircut and a few fresh greens might provide the crew with a boost in morale. The psychological impact of the fresh produce at Neumayer III is the subject of ongoing research. "We have a dedicated research team that's evaluating this with questionnaires and group discussions," says Schubert. "It seems like there is a positive effect." The EDEN ISS project is set to continue until at least 2021, with plant researchers worldwide being invited to propose studies for this unique facility.

SPLENDID ISOLATION

Every year, the Neumayer III research station, viewed here from the window of one of the Alfred Wegener Institute's helicopters, moves about 150 metres north, along with the Ekström ice shelf on which it sits. It's a lonely place, particularly during the nine-month winter, when nine crew members (three of whom share responsibility for the plants) spend the season completely detached from the outside world. During the summer, the number of scientists at Neumayer III swells to around 50, with multiple projects covering research topics ranging from air chemistry to marine ice to penguins.

Despite the isolation, there is close contact all year round between crew members in Antarctica and colleagues back in Germany. "Nowadays, it's quite easy," says Schubert. "We have a big WhatsApp group with the overwinterers, and a dedicated greenhouse chat group." But while the remote scientists can advise if something goes wrong, on-site technical expertise is crucial, just like in space. **SF**

DISCOVER MORE

BBC RADIO 4 *Listen to the president of the British Antarctic Survey Jane Francis tell Jim Al-Khalili about camping on the ice in Antarctica in this episode of* The Life Scientific ***bit.ly/jane_francis***

by **HAYLEY BENNETT** *(@gingerbreadlady)*
Hayley is a science writer based in Bristol, UK.

WILD IDEAS TO BLOW YOUR MIND

As Albert Einstein once said, "imagination is more important than knowledge." So with that in mind, here are our picks of the most radical theories in science

ALLA KATSNELSON
BRIAN CLEGG
DR PETER BENTLEY
SIMON CROMPTON
DR HELEN PILCHER
DR STUART CLARK
TOM IRELAND

DARK MATTER MIGHT BE UNDER OUR FEET

Most of the Universe is made up of dark matter. The problem is, we haven't found it. But one team thinks we could discover its imprints lurking in rocks

Most of the Universe is missing. By observing the way that galaxies spin, astronomers have calculated that there must be five times as much invisible 'dark matter' as ordinary stuff in the cosmos. For three decades, attempts have been made to find dark matter particles, but with zero success. Now, a group of astrophysicists from Europe and the US think that the answer to detecting the elusive stuff may lie in the deep past, beneath our feet.

So far, most attempts to directly detect dark matter have focused on hypothetical particles known as WIMPs ('weakly interacting massive particles'). Detectors have been built to look for the energy released when these particles hit the nuclei of other atoms, but with no collisions so far detected, it might be that WIMPs don't exist. Or could it just be that we need a more sensitive detector? The new idea is to look for the tracks of WIMPs in ancient rocks, detecting dark matter over geological timescales. WIMPs colliding with the atomic nuclei in certain rock minerals could, in theory, create tiny changes to the minerals' crystal structure. "The interaction with dark matter would make the [atomic] nucleus move some tens to hundreds of nanometres through the crystal, leaving a damage track," says Sebastian Baum at Stockholm University, who is taking part in the research. The rocks being studied could be as much as one billion years old, with WIMPs potentially leaving tracks all that time. The researchers think that their method could reach a sensitivity of around 100 times that of the best existing detectors.

"We plan to dig up rocks from 10 kilometres below the surface of the Earth via ultra-deep boreholes that already exist," says Dr Katherine Freese at the University of Michigan, who is also taking part in the study. "The point of going deep underground is that the dark matter can penetrate that far down, whereas other particles, especially cosmic rays, get stuck closer to the surface." So this'll help to reduce the amount of tracks from other potential sources.

Once the samples have been obtained, the plan is to use imaging techniques such as helium-ion beam microscopy to look for the tracks, which may be 1,000 times shorter than the width of a human hair. If all goes well with funding, the researchers hope to have their first results by 2025. If they don't discover WIMPs, it'll be back to the drawing board – again – for dark matter theorists. But if they do, it'll solve one of the biggest mysteries in science. **BC**

2 ROBOTS WILL NEVER THINK LIKE US

Artificial intelligence keeps getting smarter: it can thrash us at games, classify images and drive cars. But it can never imitate human thought

Today's AI systems are superhuman. Computer models based loosely on the neural networks in our brains are trained on vast amounts of data using huge clusters of processors. They can now classify objects in images better than we can. And as IBM and Google's DeepMind have demonstrated, they can beat us at games such as chess and Go, and even achieve the highest rank in the computer game *StarCraft II*. But at the same time, AI systems are inhuman. Even inhumane. Our AIs do not comprehend our world or their place within it.

Biological creatures are not trained once on a static pool of data in the way we train an AI. It would be like presenting a newborn baby with the complete *Encyclopaedia Britannica* and telling them, "learn that perfectly, and that's all you'll ever need". We require years of experience in ever-changing environments before we can understand our world. Research has shown that, if we're trying to focus on an object, our brains aren't fully able to filter out visual distractions until age 17, and our ability to perceive faces keeps developing until age 20. We're prebuilt to learn, having descended from 3.5 billion years of creatures who each faced life-and-death situations, in which they had to perceive and act correctly to survive. AIs have none of this. Their algorithms use highly simplified ideas of learning, mostly doing little more than data classification or prediction.

The only way we can make our AI algorithms work is by training them on large amounts of narrowly focused sets of data, with defined objectives. They are still not able to handle changing scenarios in the way we can. They do not understand cause and effect. They cannot properly link words such as 'chair' or 'vehicle' to real physical objects, because they never experience reality how we do. And while some AIs may be able to classify emotions by processing images of faces, research is still in its infancy into how an AI might actually feel emotions, empathise, or understand how its behaviour might affect us.

Over time, AIs might come closer to us. Maybe we can help them to think more like us by developing algorithms that learn and process information in new ways. But the gap between us will likely always be there. AIs do not share our evolutionary history, and they may never have a brain as complex or as fine-tuned as ours. They can become masters of the digital universes they inhabit, whether computer games, image processing, or the internet. But, for the foreseeable future, we will remain masters of our own world. PB

3 BABIES WITHOUT PREGNANCY

Artificial wombs may give premature babies a better chance of survival. But could they transform reproductive rights too?

Critically preterm babies face an uncertain future. Although a foetus is considered viable at 24 weeks of gestation, only about 60 per cent of babies born so young will survive, and many will experience life-long complications. For those born a couple of weeks earlier, the statistics are even more dire: just 10 per cent of babies born at 22 weeks are likely to survive.

Building a so-called artificial womb could potentially save these babies. In October, researchers from the Eindhoven University of Technology in the Netherlands announced that they had received a grant for €2.9m (£2.5m approx) to develop a prototype of such a device. But the project isn't the only artificial womb on the horizon. In 2017, researchers in Philadelphia transferred foetal lambs, aged between 105 and 115 days of gestation (equivalent to about 28 to 30 weeks human gestation), into a so-called biobag filled with artificial amniotic fluid. After several weeks in the bag, the lambs developed normally. And in March 2019, an Australian and Japanese research team kept younger lambs, about 95 days' gestational age, alive in a different system. Dr Matthew Kemp, who led the latter work, notes that researchers don't fully understand foetal growth in the womb, which makes replicating it a challenge. The Dutch group noted plans to roll out a clinic-ready prototype in five years, but Kemp says it will likely take much longer. And because the technology is so costly, it's unlikely to be widely available any time soon.

So far, what researchers call artificial wombs are essentially souped-up incubators. They provide a fluid-filled space in which a foetus can receive nutrients and oxygen through a 'placenta'. From there to full-on ectogenesis — incubating foetuses outside a human for the full duration of a pregnancy — is an enormous leap. But many bioethicists note that technology moves quickly, and proactively thinking through the possibilities is important. In this more futuristic vision, artificial wombs can do a lot for society, says Dr Elizabeth Yuko, a bioethicist at Fordham University in New York. It could allow people who can't carry a pregnancy for whatever reason — illness, infertility, age, or gender — to do so. It might also shift some of the childbearing responsibilities carried by women. But it also raises concerns. For example, ex-utero gestation would likely turn reproductive rights on their head, says Elizabeth Chloe Romanis, a lawyer and bioethicist at the University of Manchester. If a foetus can gestate outside a woman's body, the choice of whether or not to have the baby might be deemed out of her hands. Another issue is that our legal rights are predicated on having been born alive. "I don't think that a gestating subject in an artificial womb necessarily meets that requirement," says Romanis. "That raises some questions about human entities ex-utero that have never existed before." AK

4 DEATH IS REVERSIBLE

Earlier this year, scientists brought dead pig brains back to life, provoking huge ethical quandaries in the process

We all know that when your brain dies, you die. Without a blood supply, your brain cells start dying off rapidly in around six minutes. Then there's an irreversible loss of all neurological function in the brain and brain stem. No sign of life, no coming back, sign the death certificate

At least, that's what's supposed to happen. This year, scientists from Yale School of Medicine created the biggest commotion about brain reanimation since Mary Shelley when they reported that they'd revived the brains of 32 pigs four hours after they been slaughtered. Brains, it seemed, could be brought back to life.

The researchers hooked up the 'dead' organs to a system that infused them with a blood substitute called BrainEx, which promotes cell recovery after oxygen deprivation. The scientists found that BrainEx helped maintain the brain's internal structure and rebooted some brain cell functions such as the ability to produce energy and remove waste.

Perhaps most remarkably, they found that electrical activity between brain cells restarted. There was no sign of coordinated signals – certainly no indication of consciousness – but on the other hand the chemicals fed into the brain had been formulated to head off that possibility.

"What we are showing is that the process of cell death is a gradual, stepwise process and that some of those processes can be either postponed, preserved or even reversed," said lead researcher and neurologist Prof Nenad Sestan on the publication of his research in *Nature* journal this April.

Sestan started off trying to revive animal brain cells as a means to understand brain networks and neurological disease. But he's ended up raising far-reaching scientific and ethical questions. How do we define death? Are current guidelines on brain death in need of revision? Should we even be conducting research that raises the smallest possibility of creating consciousness?

So what now? It seems Sestan may be reeling from the possible implications of what he's half-stumbled upon. Contacted by *BBC Science Focus* six months after the publication of his research, he was reluctant to say where it left him or what the next steps are. "The period of reassessment following a study of this nature can be significant, and from a holistic perspective, probably it should be," he told us. His research group, he said, was carefully considering its next set of experiments, but it would be premature to reveal them "even in abstract terms".

Whatever Sestan's team decides to do, the cat's now out of the bag and others are bound to push his work further. With parallel research galloping ahead on cultured mini-brains and with Italian neurosurgeon Sergio Canavero claiming he's ready to conduct the first human head transplant, there'll be no shortage of Frankenstein headlines in the 2020s. It's now a question of where and when the ethicists and regulators start drawing new lines.

As a group of neuroscientists, bioethicists and lawyers noted in a *Nature* response to the news that pig brains had been partially revived. "We're reminded of a line from the 1987 film *The Princess Bride*: 'There's a big difference between mostly dead and all dead. Mostly dead is slightly alive.'" SCr

5 MUSHROOMS COULD SAVE THE WORLD

Mushrooms are pretty darn good sprinkled over a pizza or served alongside bacon, but they're even better when used to soak up toxic waste, create clothes, or revolutionise construction

It looks like 2020 will be the year that products made from mushrooms go mainstream. Strong yet biodegradable, and created using minimal resources, mushroom-based materials could help solve several of society's most pressing problems at once.

Yes, it's hard to imagine a pair of shoes, a lamp or even a house made of those soggy grey things sitting next to your baked beans as you tuck into a full English. But the edible part of a mushroom is just its fruiting body: below ground, these remarkable organisms grow a network of fine, branching digestive filaments known as mycelium, which when compacted forms a tough and lightweight material.

These days, mycelium is getting designers, engineers and materials scientists very excited indeed: not only can it be grown using unwanted resources like food leftovers or farm waste, it will grow into any shape required using a mould (ahem) and it is relatively easy to grow at scale, requiring only a food source, air and water.

And one of those food sources can be rubbish for which we have no use, such as nut husks, potato peelings, coffee cups, discarded textiles and even industrial waste. In fact, for almost any type of waste you can think of, there seems to be a species of fungi that enjoys breaking it down. There are even species of fungi that will soak up toxic heavy metals like lead and arsenic, and some that will grow on radioactive waste. Back in 2011, a species of fungus was found in the Amazon that feasts on the tough plastic polyurethane.

So far, mycelium has been used to produce everything from lightweight plastic-free packaging to super-strong and fire-proof breeze blocks. Designers are also starting to see mycelium's potential to 'grow' clothes, shoes, vases, lamps, tables and other products that have a positive environmental impact. Compared to manufacturing with plastic or concrete, which involves mining materials from the ground and treatment at high temperatures, it's a no-brainer. The only by-product? Edible mushrooms.

Some experts even believe that mushrooms and fungi could help us grow food or buildings on other worlds like Mars. A species of fungus that could feed on the barren Martian soil could colonise vast tracts of land and slowly make it more hospitable for humans – a concept known as terraforming. That's still a long way off, but here on Earth, waste-munching mushrooms are already being put to excellent use in environmental clean-up projects. One example of this is in the Ecuadorian rainforest at the site of the world's largest oil spill, where a collaboration of scientists and environmental groups plan to grow giant petrol-gobbling mushrooms on the toxic soil.

And that's all before we even consider the wider potential of the world's 1.4 million species of fungi in other areas of biotechnology and medicine. This incredibly diverse group of organisms has evolved many unique adaptations for survival in an immense number of different habitats and niches, and represent a vast untapped source of potentially useful compounds, such as antimicrobials and antivirals. The future is fungal. TI

WE'VE ALREADY FOUND LIFE ON MARS

The hunt for life on Mars is one of the hottest topics in astronomy right now. But one scientist thinks that we already found evidence of microbes, back when the Viking landers touched down in the 1970s

Life found on Mars! Surely it would be the story of the century except perhaps it was the story of last century and everybody missed it. That's the extraordinary claim of Gilbert Levin, the principal investigator of a NASA experiment that went to Mars in 1976 with the Viking landers. The Labelled Release (LR) experiment placed liquid nutrients onto Mars soil samples. The idea was that any microorganisms present would consume the food and give off carbon dioxide gas.

"We were astonished to find that we immediately got gas coming out and it continued for the full seven days of the experiment," says Levin.

At first, even Levin himself was sceptical to believe that his experiment had found life, and thought that the ultraviolet light penetrating to the surface of Mars was affecting the chemistry of the soil, and priming it to release the carbon dioxide. So he got the spacecraft engineers to move a rock and take a sample of soil from underneath. His results remained the same. Next, it was suggested that hydrogen peroxide in the atmosphere and surface of Mars was responsible. But Levin investigated the data taken by Mariner 9, a previous Mars spacecraft, and found no trace of the chemical.

"Over the 43 years there have been at least 40 theories and experiments to explain away the LR life detection results," says Levin, who contends that none of these explanations stand up to scientific scrutiny. Consequently, Levin now believes that his experiment did find life on Mars. NASA, however, points to other experiments on Viking that failed to find any sign of organic molecules in the soil samples. Without organic molecules, life would be impossible.

Levin suggests that the way out of the stalemate is to fly a new LR experiment to Mars, and has even updated the design to identify a telltale characteristic of life's chemistry called 'chirality'. But as yet, no space agency seems to want to fly the experiment. Instead, Levin is part of an experiment called HABIT, which is going to Mars onboard ESA's Rosalind Franklin rover, which is scheduled for launch in summer 2020. The HABIT experiment will look for evidence that small puddles of water form on the Martian surface at dawn. Other experiments on the rover will look for chemicals that could indicate the presence of past or present life. Positive results from such experiments may change the space agencies' minds about sending a new version of Levin's LR experiment, which looks for active metabolisms.

There can be no doubt that the scientific and public interest in looking for life on Mars is high. How ironic it would be if we find out that we already detected it more than 40 years ago. **SCI**

PLANTS COULD BE CONSCIOUS

Bad news for veg lovers – one researcher thinks there might be evidence that plants can learn and remember

Plants are smarter than most people think. Venus fly traps, for example, can count. They require two touches to spring their trap, then a further three to prompt the release of insect-digesting enzymes. Trees share nutrients via a subterranean network of fungi dubbed the 'wood wide web,' and when tomatoes are attacked by pathogens, they release warning chemicals to their neighbours via the same underground system. But are they just responding passively to their environment, or could plants be thinking about their actions? It might sound far-fetched but recent experiments have prompted speculation that the leafy wonders might even be conscious.

Pavlov's dogs famously learned to associate the random noise of a bell with a forthcoming food reward. Wondering if plants can do something similar, Monica Gagliano from the University of Sydney grew pea plants in a Y-shaped maze where they instinctively grew towards a blue light located in one of the two arms. She then presented the blue light alongside a gently blowing fan. A little while later, when the fan was presented alone, the plants grew towards it. "The plants used the position of the fan to determine where the light was most likely to be," says Gagliano.

Writing in an opinion piece, Gagliano says the study hints that plants can learn and remember in an animal-like way, and if this is the case, it raises the possibility that they might be conscious. Her critics were scathing.

Plant biologist Lincoln Taiz from the University of California, Santa Cruz, is both underwhelmed by Gagliano's data, and quick to point out that plants simply don't have the hardware for consciousness. "Plants don't have brains or nerve cells," he says, but Gagliano counters that plants *do* have a nervous system of sorts. A recent study showed how a chemical messenger called 'glutamate' triggers waves of calcium ions that spread through a plant in much the same way that an electrical impulse travels through an animal. If plants are conscious, we shouldn't expect the mechanics to look identical, says Gagliano. After all, plants and animals share only the most distant of evolutionary ancestors.

Taiz is concerned that Gagliano is anthropomorphising her research subjects and thinks that all these plant behaviours can occur in the absence of an animal-like consciousness. Gagliano, however, is circumspect. "I'm not saying that plants are conscious," she says, "but I am saying we should be open minded." Consciousness is hard to define and even harder to prove. At present, there is no experimental evidence to suggest that plants are conscious, but there's also no experimental evidence to suggest that plants aren't conscious. "Studies like mine could be used as framework to explore this issue," she says. "What we need, is data." !!!

& THERE'S AN OFF-SWITCH FOR AGEING

Long and healthy lives are on the horizon

Juan Carlos Izpisúa, a professor at the Salk Institute in San Diego, is working on an experimental technique that appears to reverse the effects of old age – albeit so far only in mice. In his experiments, animals are bred to have a condition where they age prematurely. Just days away from death, the mice are given his 'elixir' and soon start to appear younger: more active, with healthier organs, thicker fur and fewer wrinkles.

But there's a catch: Belmonte's technique involves stripping away key molecular tags on the DNA in the mice's cells. This technique, known as epigenetic reprogramming, is like wiping cells 'back to factory settings' – which inevitably has huge complications if done throughout an entire organism. As a result, many of Belmonte's test subjects, although appearing rejuvenated at first, quickly developed tumours and died. Finding a balance between therapies with an anti-ageing effect and ones that lead to tumours has proven precarious.

Belmonte's work may be at an early stage, but he is just one of many scientists who sees ageing as a molecular process in our cells that could soon be adjusted, stopped, or reversed. A gradual failing of complex cellular maintenance systems is what causes cells and tissues to get worn out and stop functioning as we get older, and many research groups claim to have found the genetic 'switch' that can reset these problems. "Cellular ageing is, in my opinion, due to accumulated cellular stresses over a lifetime," says Dr Lorna Harries, a professor of molecular genetics at Exeter Medical School. "There are 'master control points' that regulate molecular stress response that could be targeted."

Harries and her team recently found two mitochondrial genes that, when inactivated, appeared to reverse various signs of ageing in human cells grown in a lab. "So in one sense, that might be viewed as a 'switch', but the consequences of switching that switch are very complicated and we are still working them out. Nothing in biology is ever simple."

The idea of stopping or reversing ageing is truly radical – it would likely have enormous and frightening implications for the world's population, for a start. However, most researchers working in this field have a simpler goal – not to keep us young forever, but to keep people healthier for longer as we age. Rather than an 'elixir of youth', it's likely that the first therapies will reverse ageing in specific tissues, such as joints or the retina. TI

If you lived here, would you survive the winter?

UNHCR
The UN Refugee Agency

Will you give £75 to help a refugee family to keep out the bitter winter cold?

When they arrived in Lebanon after fleeing Syria in fear for their children's lives, Hanaa and her husband Abdul had no savings and no money to pay rent. The only place they could find to live was the unfinished building you can see on your right.

Give £75
to provide a Syrian refugee family with a Winter Survival Kit

There were no exterior walls. For two consecutive winters the family had to huddle together in the centre of the 'room' in a desperate attempt to keep warm. They felt every blast of icy wind and were at terrible risk of respiratory diseases like tuberculosis and pneumonia.

It is a miracle the family survived, but they cannot rely on another miracle this winter. UNHCR, the UN Refugee Agency, needs your support to help parents protect their children this winter.

Please will you give £75 to provide a refugee family like Hanaa's with a Winter Survival Kit to protect against the freezing weather?

The kit contains essentials such as a heating stove, thermal blankets, warm clothes and a tarpaulin for insulation. For a family like Hanaa's who are struggling to make ends meet and living in a desperately exposed shelter, it could mean survival.

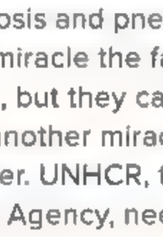
Right now, with the situation in Syria uncertain, 1.7 million refugees in Lebanon and Jordan remain unable to return home. They are living, like Hanaa's family, in unfinished or derelict buildings, or in makeshift shelters made of little more than wood and plastic sheeting. With temperatures falling, the lives of the most vulnerable – young children, pregnant women and the elderly – are at grave risk.

With a gift of £75 you can provide a Winter Survival Kit containing a stove, blankets, warm clothes and a tarpaulin to help a family insulate their home.

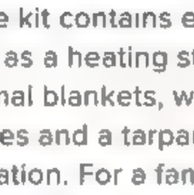
Please give today – you could save the lives of children like Hanaa's.

Give £75 now Visit unhcr.org/Hanaa
or call 0800 029 3883

With £75, you can give a winter survival kit containing:



STOVE
For heating and cooking. An absolute essential.



TARPAULIN
For insulation. Keeps the cold out and the warmth in.

BLANKET
Families left their homes with nothing. A simple blanket could save a life.

WINTER CLOTHES
Hats, gloves, scarves and coats to keep families warm, both inside and outside of shelters.

Yes, I will help Syrian refugee families survive the winter

UNHCR
The UN Refugee Agency

Please accept my gift of: ☐ £75 ☐ £150 ☐ £225 **My own choice of** £

Please post urgently to Freepost UNHCR. You do not need a stamp.

BFPAWI19C

Please debit my: ☐ Visa ☐ MasterCard ☐ Maestro

Maestro only

Card no. | | | | – | | | | | – | | | | | – | | | | |

Valid from | | – | | | Expiry date | | – | | | Issue no. | | | Maestro only

Signature | | Date | / / |

☐ I enclose a cheque or postal order made payable to UNHCR (Currently CAF cheques cannot be accepted)

Please tell us if you are happy to hear more about UNHCR's work: ☐ By email ☐ By phone

We will use your details to process your donation and to keep you up to date with our work, fundraising activities and other events. You can read more about how we use your data in our Privacy Policy **www.unhcr.org/uk/privacy-policy**
You can opt out of any communications at any time by emailing supportercare@unhcr.org or by calling 0800 029 3883

Title | First name | Last name

Address

Postcode

Email | Phone

COMMENT

BE WHERE YOUR FEET ARE

An endless to-do list and self-inflicted pressure make this the most stressful time of the year

ALEKS KROTOSKI

Aleks is a social psychologist, broadcaster and journalist. She presents *Digital Human*

BBC RADIO 4 92 95FM 198LW

PORTRAIT KATE COPELAND ILLUSTRATION JASON RA 5H

The other week, I learned a new expression: be where your feet are. It means to calm down, find yourself in the present moment, and to focus only on being in the here and now. I fear this is impossible for me; if my mental lists were ever committed onto paper, they'd require a cross-referenced almanac and possibly a bend in space and time.

The problem is, I get very excited about possibilities – particularly at this most wonderful time of year, when there are relatives to entertain, exceptional holiday feasts to whip up and complex Pinterest-perfect centrepieces to throw together. My feet are likely to be on the high street while my head's up a Christmas tree trying to figure out how to get the thing in a stand so it won't fall over and hit grandma on the head.

So I think my expectations and enthusiam rarely match up to reality. I get inspired by beautiful things I see on the front covers of magazines (when my feet are at the supermarket, and my head is trying to calculate how many days off from school I have to fill with activities), and then, when I attempt to make them, I find they take so much longer to whip up than I anticipated.

This is different from FOMO (fear of missing out), and of course I suffer from that too. This is about managing expectations – both my own, and what I imagine other people's are. And I'm not alone: countless websites offer tips on how to tackle the stress of the holidays, and all of them boil down to the same thing: keep things in perspective. Yeah, that's nice, but I haven't even started the Christmas wreath installation, and the guests will be here in 30 minutes. Why do I do this to myself?

"Being everything to everyone is not a great way to deliver a lovely holiday to the people you care about"

I have a perfectionist streak in me. I felt this pressure acutely when my daughter was born, believing I didn't live up to society's extremely high illusion of what a mother is supposed to be. It took several years before I admitted I was suffering from postnatal depression. By that time I was on my way out of the deep, dark hole, and while the holidays don't throw me back there – thank goodness – the advice the American Psychological Association offers when it comes to managing your mental health around the holidays reminds me of the language used to talk about postnatal depression. Both talk about rigid thinking, inadequacy and feeling overwhelmed.

It's ironic, perhaps, that the phrase "Be where your feet are" arrived into our house via a children's book of the same name, but kids' stories are life lessons told in words of two syllables or less. And my lesson is this: being everything to everyone is not a great way to deliver a lovely holiday to the people you care about, especially when everything you're being is what you think people expect. So throw the interactive animated flower arrangements out with the bathwater, and try to find your feet among all the pine needles. It will make the season bright for the right people, and for you. **SF**

COMMENT

RESOLUTIONS ARE WORTH IT

If you find your well-intentioned resolutions tough to keep, read on...

Learning Mandarin? Going vegan? Giving up alcohol? Many of us will start 2020 by making a resolution. Sometimes those resolutions stick. Often they don't. What can you do to keep yours going?

Well, the first thing you can do is junk the widespread belief that New Year's resolutions inevitably fail. A 2002 study published in the *Journal Of Clinical Psychology* looked into how successfully people keep their New Year's resolutions. The researchers took 159 people who made a New Year's resolution (to lose weight, quit smoking, or exercise more) and 123 people who had similar goals but hadn't yet made a resolution. Six months later, 46 per cent of the 'resolvers' said they had been successful in achieving at least part of their goal, compared with just 4 per cent of the non-resolvers.

So is it better to set yourself one New Year's resolution at a time? Not necessarily. A few years ago, researchers from Stanford University took 200 inactive, overweight volunteers who were keen to lose weight and split them into three different groups. The first group of people were put on a diet and then got exercise advice a few months later. A second group got exercise, with dietary advice some months later. A third group got both exercise and dietary advice from the start. The researchers then tracked the progress of all three groups for a year. They found that the people who changed both their diet and their exercise regime at the same time were the most successful.

"The more you can build activity into your life, the more likely you are to succeed"

Many people think that sticking to resolutions is all about willpower. It isn't. Resolutions that rely on abstract, distant goals ("I will get fitter so I can live longer") are no match for short term desires ("that sofa looks comfortable"). Changing your ways requires help. Sign up with a personal trainer you like, persuade a close friend or loved one to join you in a weekly Zumba class, or buy a dog that howls if you don't take it for a walk (mine does). The more you can build activity into your life so you can't avoid it, the more likely you are to succeed.

If you want to stick to your New Year's resolutions:

1. Be specific. Don't just say to yourself, "I must do a bit more exercise". Download the NHS app, *Couch To 5K*, which will guide you through a detailed approach on how to get fitter.

2. Tell your friends and family what you are doing and ask them to join in. We are social creatures and do much better with the support of others.

3. Reflect on your past successes. Most people have managed to stick to a resolution at some point in their lives. What did you do last time that worked? What resources do you have that you can call on?

Good luck, and happy New Year! **SF**

MICHAEL MOSLEY

Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor* The new series will be coming out in January 2020.

BBC TWO

PORTRAIT KATE COPELAND ILLUSTRATION OVADIA BENISHU

SCHIIT
CO·UK

HOT

MAGNI 3+ AND MAGNI HERESY

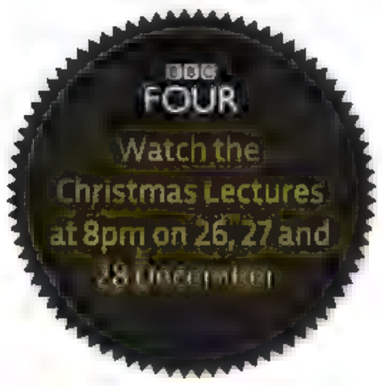
2.4W HEADPHONE AMP AND PREAMP
PERFECT WITH MODI 3

FROM £110 EACH!

electromod
the sound connection
www.electromod.co.uk


PATRICK MCMULLAN PHOTOGR

YOU CAN'T IGNORE THE NUMBERS



For nearly 200 years, the Royal Institution Christmas Lectures have gathered people together at Christmastime to share in the wonder of science. This year's lectures are given by mathematician **HANNAH FRY**. She spoke to **AMY BARRETT** about the honour, how maths is so pervasive in our daily lives and her studies into the patterns of human behaviour

WHY ARE THE CHRISTMAS LECTURES IMPORTANT?

The Lectures have been televised since about the 1950s but have been going since 1825. Back then, as I understand it, Faraday – the guy who discovered electricity – and a few of his mates decided that they wanted to impart their wisdom onto local children. In my mind, they grabbed loads of Victorian children off the street, made them sit there, and then talked science at them for an hour for several nights in a row.

The Lectures are a place where real experts, real scientists, real mathematicians, can have a chance to explain why their subject is so exciting and why they're so passionate about it – in a way that appeals to all generations, and in a way that includes big demonstrations and experiments, and loads of audience interaction. They're a really friendly but intriguing and thought-provoking addition to your Christmas holidays.

WHAT WILL YOUR LECTURES BE ABOUT?

In all of that time, they have only let three mathematicians previously do the Lectures, which I think is astonishing, right?

So, I make the fourth occasion. But I'm not going to do maths in the way that you might have seen it before. I'm not going to talk about prime numbers or geometry or a bit of algebra. None of that stuff.

The Lectures this year are called *Secrets And Lies*, and really, they're about how many aspects of our lives are secretly underpinned by mathematics. We talk to someone from the Premier League who analyses how players act on the pitch, and find out how you can use maths and data and statistics to actually make your own luck, to give your team a better chance of winning. We talk about how to use mathematical knowledge to bend the world to our will, and how you can make a computer help to diagnose cancer.

And in the final lecture, we talk about what the limits are. How much we want to entrust decisions in our world to mathematics, and to these mathematic algorithms that are so pervasive. As part of that lecture, we're going to do a deepfake on an audience member. I think this will be the first time that anyone's done that on TV.

CAN YOU EXPLAIN WHAT A 'DEEPFAKE' IS?

A deepfake is faked video footage. It's quite easy to get an impressionist to fake a piece of audio from a famous person, so it sounds like they're saying something that they haven't. Or, if you're a bad singer, to use AutoTune to make you sound better. Likewise, photographs are very easy to fake by photoshopping things in and out.

Deepfakes are the same but with video footage. There are some very clever and sophisticated mathematical techniques behind this that aren't totally dissimilar to the filters you get on Instagram or Snapchat that change your face into a rabbit or whatever. But instead of changing your face into a rabbit, you can change your face into somebody else's.

Which means that I can sit there and say, I don't know, "I am the king of the world" or "give me all your jelly babies" – but instead of me saying it, you could effectively make it look as though Tom Cruise was saying it. Saying anything, and doing anything, that you want him to be.

THERE'S MATHS IN THAT?

Yeah. The whole process of transcribing what's going on in those pixels, how the face is moving, what that means in terms of a 3D object, ie, your face, and instead replacing it with somebody else's face... it's incredibly mathematical.

But I think that this is a really good example of where it's not just a mathematical process that sits in a textbook and you're done. This has much wider potential implications for the world. We might end up in a situation where nobody knows what's real and what's fake any more. Where you have people denying real footage claiming that it's fake when it isn't.

It's not just this little bit of clever maths – it's something that has the ability to puncture all truth and reality and everything that we know to be real at the moment within the world.

WHEN I THINK ABOUT MATHS, I THINK BACK TO GCSE, WHICH WAS QUITE A DRY IN COMPARISON TO WHAT YOU'RE TALKING ABOUT...

Yeah. That's a few fractions, a bit of percentages, a couple of circle theorems.

IS THERE SOMETHING ABOUT HOW MATHS IS TAUGHT THAT MEANS WE MISS OUT ON THESE

"I'm not going to do maths in the way that you might have seen it before. I'm not going to talk about prime numbers"

DR HANNAH FRY
(@FryRsquared)
Hannah is a mathematician, television presenter, podcast host and author. Her latest book, Hello World: How To Be Human In The Age Of The Machine, *was published in paperback earlier this year.*

BBC/FJRNACE LTD

ABOVE Hannah Fry is only the fourth mathematician to give the Christmas Lectures in their 195-year history

PAUL WILKINSON PHOTOGRAPHY

INTERESTING EXAMPLES FROM REAL-LIFE?

Yes and no. The analogy often used is that maths teaching in school is like being taught music by only ever playing scales, and never listening to any other music. If that's all you know exists, you would think, "What is the point of music?" Yet, ask anyone who's alive and they know what the point of music is.

I think it is a real shame that that's the way that maths is taught. It's so blinkered and so focused and just misses out on this incredible wealth, this incredible extra, mirrored universe that exists, like our universe but just slightly more mathematical, sitting underneath us.

But I also think that it's sort of the way that needs to be. I wish it wasn't, but you do have to learn. When you're learning the piano, you've got to learn the scales. It's boring, no one enjoys it, but you have to.

That's why I think things like the Christmas Lectures are important. To tell these incredible and surprising and counterintuitive stories, making them known to the wider public.

YOU'VE SAID MATHS UNDERPINS MOST OF WHAT WE DO. HOW DO I INTERACT WITH MATHS ON A REGULAR WEEKDAY?

So you get up, maybe you turn on your radio, using a mobile phone perhaps, which is communicating with satellites to get those sound waves to your phone. The pixels on your screen, how those are designed, it's in that whole process.

Maybe you're putting on a nice new jacket as you leave the house. The way that someone transformed a flat piece of fabric into a structure around your body that can be scaled up and scaled down depending on the size of the person that's wearing it – that's maths, maths, maths.

Let's say then you go get the train to work. All those train timetables – that is maths, maths, maths. And we haven't even got to any people-y stuff yet.

I HAVEN'T EVEN DONE ANYTHING YET!

Right? The problem with maths is that you can't see it. You can't hold it. You can't point to it and say that's what it is. It's completely invisible.

So it's really easy to turn a blind eye to just how pervasive it is – to just how much of our modern world completely relies on it, is built on its foundations. When you start looking for it, I've yet to find a single thing about humans, or about our universe, or anything, where maths has nothing to say.

THAT CAN BE A BAD THING TOO, CAN'T IT? THE FACT THAT WE 'TURN A BLIND EYE' AND DON'T REALISE HOW MUCH OF OURSELVES IS BEING COLLECTED AND THEN ANALYSED IN THIS MATHEMATICAL WAY...

Yeah, totally. I mean, I think Cambridge Analytica hit us all quite hard. We hadn't realised just what the implications of what we were doing.

The thing about Cambridge Analytica is that they really weren't unusual. They weren't a group of people who were doing something really incredible, they were a group of people who were using the system in exactly the way that it was designed to be used. So much of ●

everything that's around us now is designed to analyse us or collect our data, to work out what we're going to do next and to use that information, either to sell us something or to improve something.

This is both good and bad, it's not just universally negative. But yes, it's very easy to turn a blind eye to that.

CONSIDERING THE WORK YOU'VE DONE IN THIS AREA, ARE YOU NOW MORE CONSCIOUS OF WHEN YOU GIVE YOUR OWN PERSONAL DATA?

Yes and no. I have ad blockers, and I have lots of different email addresses with nonsense names and all of that stuff. I try to maintain a level of anonymity and always say no to cookies, always go through and tick 'no partners' or whatever.

But on the flipside, if it's 12:30 at night and I just want to read something on a website, and it pops up and says, 'Do you accept cookies?', I'm like, "'For God's sake, just take it," like everyone else.

BUT WHO *REALLY* KNOWS WHAT THEY'RE AGREEING TO WHEN THEY TICK THE BOX...

You're agreeing to being tracked, basically.

BY ANYONE?

Pretty much, yeah. So the way that it works is there are data brokers who deal and trade in your data. On a server somewhere there will be a file with an ID number that represents uniquely you, that you'll never have access to. That file is not a record of everything you've ever typed into Google. In many ways, it's slightly cleverer than that and slightly freakier.

It's everything that's inferred from the stuff you've done online: things like your age and your income bracket, but also things like your sexuality, or the difference between your true sexuality and your declared sexuality. Whether your parents got divorced when you were young. Whether you've ever used drugs, whether you're gullible, whether you're a risk-taker. When you agree to cookies, you're essentially allowing companies who are targeting a particular group of people to find out these things about you. Maybe they're targeting 'risk-seeking people whose parents got divorced'. I can't imagine what they'd be selling them. When you click onto a website with cookies, essentially you're agreeing that they can send off a little flag to that data broker, who then knows that someone in their target group is on that website. Then they can serve you up an advert from one of their clients who wants to target someone like you.

"So much of everything around us now is designed to analyse us or collect our data, to work out what we're going to do next"

But we also know this anyway, right? I mean, we know that the adverts that we see on the internet are freakily accurate. You talk about wanting to buy a dog one day, and the next day you're seeing adverts for dog beds, you know?

It's not that your phone is listening to you, because it would be a technical challenge to do that. It's that these algorithms are so good at understanding your behaviour that they can know that you want a dog bed before you've even really decided that buying a dog bed is the next thing that you need to do, after you've decided to buy a dog.

SO IS THERE NO SUCH THING AS FREE WILL OR LUCK OR CHANCE ANY MORE?

That's an incredibly important point, and part of what these Lectures are about. We want to demonstrate just how powerful and pervasive these mathematical techniques are, but also to explain the limits to them.

If I serve you up an advert for a dog bed, for instance, that's not going to change whether you get a dog or not. Maybe it might make a bit of a difference, perhaps very subtly, but we're talking about tiny, tiny, tiny changes. You still have your own mind. There's still free will, there's still all kinds of randomness and uncertainty that these algorithms and these mathematical techniques cannot cut through.

DO YOU REMEMBER THE FIRST CHRISTMAS LECTURES YOU EVER WATCHED?

I think they were always there, to be honest.

WILL YOU WATCH YOUR OWN THIS CHRISTMAS?

No chance. I'm not very good at watching my own stuff back. No one likes that though, do they?

The sound of my own voice is okay, I'm used to that – it's just the moving pictures. Maybe I need to deepfake myself so it's not my actual face, and then I can watch it... **SF**

DISCOVER MORE

FOUR *The Royal Institution Christmas Lectures with Hannah Fry will be broadcast at 8pm on BBC Four on 26, 27 and 28 December*

You can read the full interview with Hannah on ***sciencefocus.com*** *Subscribe to the* Science Focus Podcast *and listen to our full interview with Hannah in an upcoming episode* ***sciencefocus.com/science-focus-podcast***

IS ANYBODY IN THERE?

by AMY FLEMING

Groundbreaking new research has discovered that 15 per cent of coma patients might be conscious and aware of their surroundings. Now, the race is on to find out ways to bring them back.

The rare occasions when people in vegetative states 'wake up' after years or even decades of unresponsiveness always make the news. We're fascinated by the details behind the jubilant headlines: what was it like waking up from an extremely long sleep? What had been going on in their minds? Were they frozen in time? Or had they, perhaps, been aware of what was going on around them the whole time?

It's hard to gauge how many people are currently in a persistent vegetative state, languishing in a care-home bed, their inner lives a mystery. The causes of their brain injuries are diverse – from oxygen starvation (which could be due to stroke, heart attack, near-drowning and more) to trauma caused by a blow to the head – and there is no central register. But neuroscientists estimate there are thousands in the UK, and they are increasing in number, as doctors get better at saving lives in the aftermath of brain injuries.

Thankfully, doctors are also getting better at figuring out what is going on in these patients' minds. "There have been huge discoveries over the last 15 years," says Adrian Owen, a professor at the Brain And Mind Institute at Canada's Western University. The first of these, he says, was "a 2006 paper where we showed that some of these patients are actually aware, and then the 2010 paper where we started to communicate with some of them."

From the data so far, 15 to 20 per cent of patients show signs of concealed consciousness, and researchers are now making great strides in diagnosing the condition, understanding its mechanics and even working on treatments that could increase the chances of rehabilitation.

INTO THE UNKNOWN

Technically speaking, coma usually only lasts for days or weeks after an injury. "Typically, you don't go through the screen of a car and straight into a vegetative state," says Owen. "First, your eyes are closed and you're on life support." This is a coma – an acute disorder of consciousness. It's only after a patient emerges from the coma that they either wake up, are diagnosed with brain death (for which there are clear metrics), or enter a prolonged disorder of consciousness.

"This may be a vegetative state, or what we call a minimally conscious state, or MCS," says Dr Davinia Fernández-Espejo, a senior lecturer at the University of Birmingham, whose study earlier this year identified the physiological cause of vegetative state, and who is developing a therapy to treat it.

In a vegetative state, the patient is off life support, able to breathe on their own and digest food. "They often appear to be awake," says Fernández-Espejo.

ILLUSTRATION SÉBASTIEN THIBAULT

LEFT Adrian Owen from Canada's Western University led the team who first began talking to patients who were otherwise deemed unresponsive

"Their eyes are open and moving around a little bit." They might startle if you blast some Led Zeppelin, or withdraw their hand if you poke them, she explains, "but they still don't respond to the environment in any intentional way that may make us think that the patient is aware."

Minimally conscious people show flickers of awareness, but "they're still incapable of communicating – verbally or non-verbally."

DETECTING CONSCIOUSNESS

So how can doctors tell if there is concealed consciousness? Owen has developed a method using an fMRI scanner. He asks a series of questions: to answer 'Yes', the patient imagines they're playing tennis, while to answer 'No' they take a mental stroll around their home. If they're conscious, different areas in the brain will light up: motor activity for 'Yes' versus spatial awareness for 'No'.

It's in intensive care units (ICU) where doctors and families often have to decide whether a patient has prospects for survival or whether life support should be turned off – and mistakes will have inevitably been made. But now, says Owen, "we can apply these techniques in the ICU, maybe a week after their injury, and both diagnose them more accurately and make predictions about who's going to recover and who isn't."

However, fMRI scanners can't simply be wheeled into an ICU. So, in a small 2019 study, Columbia University-based neurologist Jan Claassen showed that an electroencephalogram (EEG) that measures brain waves, combined with machine learning, could be used instead to detect concealed consciousness in ICU patients. Once again, the patients were asked questions and their brain activity was observed. Within four days of their injuries, 15 per cent of the 104 patients in the study were found to have hidden consciousness, despite being unresponsive.

Of those patients, 44 per cent progressed out of their vegetative state, to some degree, within 12 months.

Owen, meanwhile, has developed a new portable technique, "based on a method called functional near-infrared spectroscopy, which like fMRI looks at the amount of oxygen in the blood, only with little lasers. It's pretty cool. We had a paper out last year showing that we could use it effectively to communicate with a patient," says Owen. The team asked the patient if he felt safe and if he was in any pain. "He wasn't," says Owen, "and he felt at peace with himself as much as one could."

One of Owen's Canadian patients, Juan Torres, had an acute brain injury after choking on vomit, but made an unprecedented recovery to the extent that he could clearly recount his three-month vegetative experience. He'd witnessed doctors declaring his brain irreparably damaged, and his family's devastation. "He said he was always trying to move but it just wouldn't happen," says Owen.

It's not that vegetative patients are paralysed – that's a different condition called locked-in syndrome, where there is obvious consciousness but the connection between the brain and spinal cord is severed. Fernández-Espejo's research group has discovered that vegetative patients with covert consciousness have "damage in some fibres connecting the thalamus in the centre of the brain, and the motor cortex, which controls movement. Because this pathway is injured, these patients are not able to voluntarily control their behaviour."

Many of these patients will have severe damage to other parts of their brains, too, "but the damage to other cognitive functions is not as severe as it looks from the outside, because of these problems with controlling the movement," says Fernández-Espejo.

Her group is now recruiting patients to trial a non-invasive form of electrical stimulation. The hope is that this will encourage "the neurons that are still there to work harder to compensate for the

"AN EEG, COMBINED WITH MACHINE LEARNING, COULD BE USED TO DETECT CONCEALED CONSCIOUSNESS"

ones that were lost, so the patient can make some small movements." This could then enable patients to use technology to communicate, in the way many locked-in people can, and get them to a point at which rehabilitation therapies are possible.

"I'm really excited to be at this stage," says Fernández-Espejo, "after years of being been able to say to relatives, 'Yes, the patient is conscious,' but then not being able to do anything about it. Now we have a mechanism that we can exploit to try to help patients get better."

A NEW HOPE

Dr Theresa Bender Pape, a clinical neuroscientist with the US Department of Veterans Affairs based at Northwestern University in Chicago, is currently trialling another non-invasive treatment called transcranial magnetic stimulation (TMS) to alter brain activity in vegetative patients. The results are due for publication in 2020, and are promising. The idea is, she says, "I get one neuron to talk to the next neuron to talk to the next neuron, so I'm altering neural activity in areas remote from the site of stimulation over time."

Pape has also developed a treatment called Familiar Auditory Sensory Training (FAST). It involves close relatives recording well-worn family stories and jokes, and these recordings being played to the patient repeatedly. In 2015, a placebo-controlled study assessing FAST's impact showed that patients who received the therapy recovered sooner and more extensively than those that didn't. And in answer to relatives wanting to know whether their loved ones could hear them, MRI scans showed patients' brains lighting up in response to the stories, in regions associated with language and long-term memory. "I love when patients tell me that they remember the stories," says Pape.

Pape's star TMS recoverer, Laura Gonzalez, is now sitting up, communicating non-verbally and living back at home, after more than 18 months in a vegetative state. After around 20 TMS treatments (out of 30), she recalls, "I walked in the room and said, 'Hey Laura!'" When Laura looked back in acknowledgement, she says, "I thought: 'Did I just see that?' The hair on the back of my neck stood up." **SF**

DISCOVER MORE

BBC RADIO 4 *Listen to Adrian Owen tell Jim Al-Khalili about his research on people in comas in this episode of* The Life Scientific ***bit.ly/Adrian_owen***

by **AMY FLEMING**
(@Amy_Fleming)
Amy is a freelance science journalist whose work has appeared in The Guardian, Newsweek *and the* Financial Times

SCOTT HENS, ILLUSTRATION SÉBASTIEN THIBAULT

WHY POSITIVITY IS OVERRATED

by Andy Ridgway

Cheer up, it's Christmas! How many times has someone said that to you? If the answer is 'a lot', you're not alone. It's the time of year when we're supposed to drop our slightly cynical view of life and embrace the warm, fuzzy glow of the festive period. For the most famous curmudgeon of all, Ebenezer Scrooge, it took a few visits from ghostly spirits for him to adopt a more positive outlook towards Christmas, and life itself. Scrooge did, after all, live in a time before the self-help book. But today you can hardly step in a book shop without spotting brightly coloured covers that promise our lives will be transformed if only we can embrace the positive us. Internet memes, TV ads, pop music – they all carry the same message. Be positive. Reach for the stars. Focus on your dreams and they will come true.

But a growing body of research is showing that being positive and an optimist is not all it's cracked up to be. Adopting a more pessimistic approach to life might actually mean you earn more, as well as being healthier and happier. In other words, there is a scientifically proven reason to say 'bah, humbug!'

One of the real dangers, it seems, in always being positive is that you just don't get stuff done. As Dr Gabrielle Oettingen, a psychology professor at ●

GETTY IMAGES

"AS PLEASURABLE AS POSITIVE FANTASIES AND DAYDREAMS ARE, THEY ARE ACTUALLY REALLY HURTFUL"

New York University and the University of Hamburg said in a talk at an international conference: "Dreamers are often not doers". It's something she has evidenced through 20 years of research.

"We have a whole line of findings showing that the more positively people fantasise or daydream into the future, the less well they do in trying to implement their desired future," Oettingen tells us.

Her research spans many facets of our lives. In one study, the more positive the dreams of those on weight-reduction programmes, the fewer pounds they shed. In another, university graduates who positively imagined an easy transition into work life ended up earning less money two years later than more pessimistic graduates. And people who positively fantasised about getting together with someone they fancied were less likely to be dating them six months later.

"So it seems that as pleasurable as these positive fantasies and daydreams are, and as good they are for exploring various possibilities in our futures, when it comes to implementing these wishes, they are actually really hurtful," says Oettingen, who has written a book based on her research, *Rethinking Positive Thinking*. "This is not only in the physical health domain, but also in psychological health. We find that the more people fantasise about a positive future, the less depressed they are at that moment but the more depressed they get over time."

What Oettingen's research shows is that when people are encouraged to daydream about something like landing a fantastic new job, or getting together with someone they have a crush on, they feel like they have already achieved their goal, so they relax. "These positive daydreams sap their energy and we need this energy to implement the dreams," she says. The solution is to give people what Oettingen calls 'a healthy dose of reality'. This involves them identifying the obstacles that stand in their way and thinking about how they will overcome them.

There are parallels between what Oettingen has been finding, and research into the long-term dispositions of optimism and pessimism. There's no doubt that having a glass-half-full outlook on life can have its advantages. There are numerous studies showing that optimism can help with resilience when times are tough. It can affect how others perceive us too – influencing our powers of persuasion in our work life. "The main way to convince someone to cooperate with you is to be able to convince them that you are a highly able person and the best way to do this is to really believe it yourself," says Dr Chris Dawson, an economist at the University of Bath, who researches the influence of optimism and pessimism on career success. "If you're optimistic you are more likely to do that."

COPING MECHANISMS

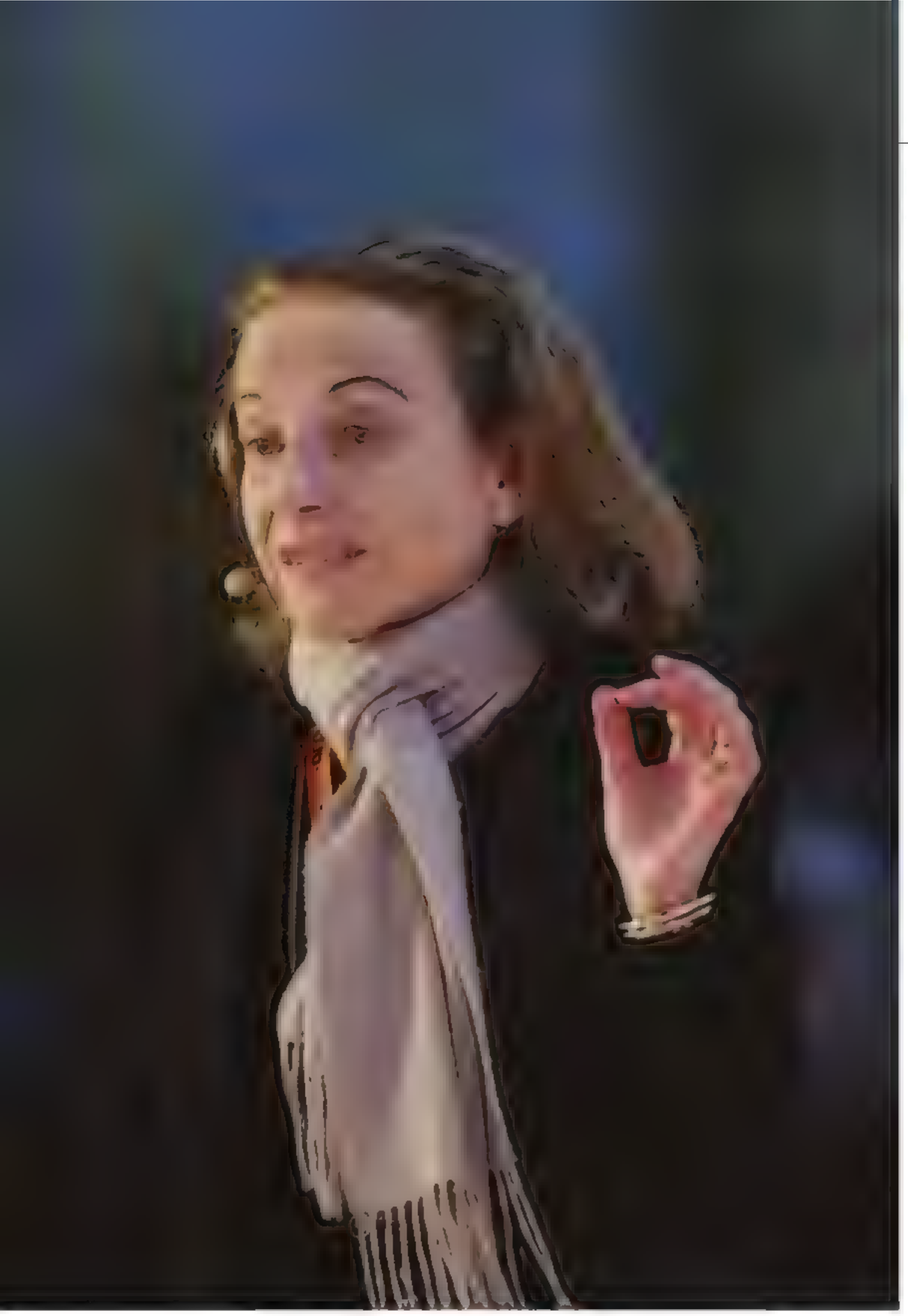
But it's really not as simple as optimism is good and pessimism is bad, like we're often led to believe. The truth is that it depends on a lot of things – not least of which is who we are as a person. Take, for example, those of us who have a tendency to be anxious; to worry about anything from an exam, to a sports competition or a job interview. What many anxious people do is intuitively adopt a technique that psychologists call 'defensive pessimism'. They set low expectations for what might happen and ruminate over all the bad things that might crop up, thinking about what they would do if they did. So in other words, just like Oettingen's 'healthy dose of reality', defensive pessimists tend to think about the obstacles and then figure out solutions for them.

In research studies, defensive pessimists are often pitted against strategic optimists – those with a sunnier disposition who actively avoid reflection on what might happen. From arithmetic tests to dart-throwing competitions, the defensive pessimists perform just as well as the strategic optimists. Where things really get interesting though is where researchers try to get the pessimists to be more optimistic, to relax and not think through what might happen. They don't do nearly as well in the tests. It's the same for the optimists too. Get them to think about all the bad things that might happen, and they don't do as well either.

Dr Julie Norem, a psychology professor at Wellesley College in the US, carried out a study in which defensive pessimists were instructed not to consider what might go wrong in an activity. The researchers also calmed down the pessimists beforehand. They found that the pessimists got super-anxious when they performed the task and they didn't do nearly as well. "Once they [the defensive pessimists] start performing it, the anxiety comes flooding back," says Norem. "So defensive pessimists are people who have high levels of anxiety and the strategy of breaking a situation down into small concrete pieces moderates those levels a bit. But they are still not calm; they can take that

RIGHT Dr Gabrielle Oettingen says that positive thinking isn't always beneficial

ALAMY



residual anxiety and use it as energy." In contrast, getting the strategic optimists to think about the bad things just makes them worry. "The risk for someone who is optimistic is that they will make themselves anxious in ways they don't know how to handle," says Norem.

That doesn't mean though that each of us is completely inflexible in whether we are an optimist or pessimist at any given moment. It means that whether a more optimistic or pessimistic approach is best may depend on the task in hand. "If you have got a group brainstorming situation, defensive pessimism isn't going to be a big advantage because the point of brainstorming is you get all kinds of ideas on the table, regardless of whether they are good or not," says Norem. "But then there is a next step where you choose which ideas you are going to implement and how you'll implement them. Here defensive pessimism is probably going to excel."

HEAD FOR BUSINESS

Perhaps one of the most surprising demonstrations of the power of pessimism comes from the world of business – something that would have been close to Scrooge's heart. A study published in 2018 by researchers at the University of Bath, London School of Economics and Cardiff University showed that business owners with above average levels of optimism earned 30 per cent less than pessimists.

For an economist, whether you are an optimist or a pessimist is all about whether you have 'miscalibrated beliefs'. An optimist is someone who expects things are going to work out well in the future, when they won't. A pessimist is someone who doesn't expect things to work well in the future, when they will. Sitting between the optimists and pessimists are the realists, who tend to accurately predict how well things will work out. This has consequences if you're starting a business. "So with optimists, it tends to lead to too many starting out as entrepreneurs because they believe they have what it takes to be successful, the next Bill Gates or whatever," says Dawson. "Optimists start projects that no one with any sort of realism would undertake." On the other hand, pessimists underestimate their ability and only pick the best projects. It's because they only pick the best projects that they tend to earn more money, but it also means they miss out on getting involved with projects that would have worked out.

So how can those of us with an optimism bias learn from the pessimists among us? The good news is that, unless we're highly optimistic or highly pessimistic, we have some flexibility in our mindset. "There is some evidence that you are not doomed to have one perspective or another," says Norem. "We find a lot of people use defensive pessimism in a particular aspect of their lives they are anxious about, but not their entire lives. So people might be defensive pessimists about their finances but they are optimistic and outgoing in their social lives."

As for how to be more pessimistic if you're an optimist, Norem has some tips. "If you're not a defensive pessimist, you can get some of the advantages by recognising the risks of overconfidence and saying to yourself, maybe things will go well and that's great. But it doesn't cost me that much to stand back and spend some time thinking about what might go wrong. Or it's probably easier to make friends with a defensive pessimist and have them help you walk through it."

Now, it would be easy to think that shunning positivity, or dialling it back at least, would turn us into bad people. A bit of a Scrooge, you might say. But that's not necessarily the case, says Oettingen – it all depends on what you wish for before you plan how you'll overcome the obstacles. "The wish does not need to be an individual wish for myself, it's often geared towards taking on a responsibility for others," says Oettingen. "It just needs to be a wish that's dear to me, and the wish may be that I will support a relative, or I will help my friend, so it's not that the wishes need to be self-centred."

But when it comes to thinking about those wishes, let's hope it doesn't take a visit from some ghostly spirits to nudge us in the right direction. **SF**

by ANDY RIDGWAY
(@AndyRidgway1)
Andy is a freelance science writer based in Bristol

DISCOVER MORE

In this episode of Health Check, *Claudia Hammond talks to Dr Martin Seligman about why optimism is not only good for your health, but could also help you live longer.* ***bit.ly/health_optimism***

SPECIAL EDITION

ONLY £9.99 INC P&P*

FROM THE MAKERS OF BBC Sky at Night MAGAZINE

THE GUIDE TO THE UNIVERSE

The latest special edition from *BBC Sky at Night Magazine*, *The Guide to The Universe* takes you on a journey from the Solar System to the edge of space to encounter the familiar and exotic objects that make up the Universe.

Beautifully illustrated throughout, with expert and clear-cut descriptions, it will give you a new perspective on our place in the vastness of space.

PLUS subscribers to *BBC Science Focus Magazine* receive FREE UK delivery on this special edition.

ORDER YOUR COPY TODAY

www.buysubscriptions.com/Universe2020

Alternatively call 03330 162138† and quote 'Guide to the Universe Print 1'

† UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) and are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). Outside of free call packages call charges from mobile phones will cost between 3p and 55p per minute. Lines are open Mon to Fri 8am–6pm and Sat 9am–1pm.

*Subscribers to *BBC Science Focus Magazine* receive FREE UK POSTAGE on this special edition. Prices including postage are: £11.49 for all UK non-subscribers, £12.99 for Europe and £13.49 for the Rest of World. All orders are subject to availability. Please allow up to 21 days for delivery. Please note your copy will be dispatched when available from 19 December 2019

Q & A

ALL YOUR QUESTIONS ANSWERED

THIS ISSUE'S EXPERTS

DR ALASTAIR GUNN
Astronomer, astrophysicist

ALEX FRANKLIN-CHEUNG
Environment/ climate expert

ALOM SHAHA
Science teacher, author

PROF ALICE GREGORY
Psychologist, sleep scientist

DR HILARY GUITE
Former GP, science writer

CHARLOTTE CORNEY
Zoo director, conservationist

DR HELEN SCALES
Oceans expert, science writer

DR CHRISTIAN JARRETT
Neuroscientist, science writer

DR EMMA DAVIES
Chemistry expert, science writer

LUIS VILLAZON
Science/tech writer

JULES HOWARD
Zoologist, science writer

PROF ROBERT MATTHEWS
Physicist, science writer

GETTY IMAGES

TAMSIN NICHOLSON, WARWICKSHIRE

WHY ARE LITTLE DOGS SO MUCH MORE ANNOYING THAN BIG DOGS?

Anecdotally, it seems that small dogs are yappier, more excitable and more aggressive, and genetic differences between breeds may be at play here. However, a 2010 survey of 1,276 dog owners in Austria found that the owners of smaller dogs may be at least partly to blame, as they tend to give their dogs less attention and be less consistent with obedience training. Dogs are pack animals, and when their owners are not assertive enough, the dogs often assume the leadership role, resulting in louder, more aggressive behaviour. ***LV***

TRISTIN QUINN, TULLAMORE, IRELAND

IF GLOBAL WARMING INCREASES RAINFALL, COULD THE EXTRA CLOUDS BLOCK SUNLIGHT AND HELP COOL THE EARTH?

The link between clouds and global temperature is complicated. On one hand, clouds block sunlight and reflect it back into space, cooling the Earth. On the other, they trap warmth radiating from the Earth's surface, increasing temperatures.

The balance between these two opposing effects varies from cloud to cloud. Low clouds, for example, tend to be quite opaque, meaning that they cool the planet more than they warm it. In contrast, wispy, high-altitude clouds allow most sunlight through but are effective at preventing heat from escaping, creating a warming effect. When you add up these effects on a global scale, clouds currently have a net cooling effect on the planet, lowering global temperatures by around 5°C.

Scientists predict that climate change will increase evaporation, leading to an increase in rainfall globally – although there will be considerable variation on a regional level. But increased rainfall does not simply translate into more clouds. Instead, changing conditions will affect how and where clouds form and how they behave.

In some areas, climate change will probably cause more low clouds to form, which could offset a rise in global temperature. In mid-latitudes, however, low cloud cover is expected to decrease. Meanwhile, the paths followed by tropical, mid-altitude storm clouds are expected to shift towards the poles, into regions with less sunlight, dampening their cooling effect. Plus, high-altitude clouds are predicted to increase in altitude, which would have a heating effect. This is because higher clouds are colder, and absorb heat radiating from Earth just as well, but retransmit more of this heat back to Earth (rather than out into space).

It's hard to predict how much these processes might warm the planet, as they could trigger positive feedback loops, accelerating a rise in temperature. Clouds are notoriously difficult to predict with certainty, but most climate models agree that changes in clouds will have the net effect of amplifying rising temperatures. ***AFC***

KEALAN BRION, WHITBY

IF YOU HAD A STRONG ENOUGH MAGNET, COULD YOU PULL SOMETHING MAGNETIC OUT OF A BLACK HOLE?

Astronomers have found that the magnetic field strengths near supermassive black holes can be as strong as their intense gravitational fields. In fact, these magnetic fields are able to expel material from the vicinity of the black hole to form highly energetic outflows called 'jets'. However, this process is not acting on material that has already passed beyond the black hole's event horizon (where the gravity is so strong that not even light can escape). Such material would need to be accelerated to at least the speed of light to escape, and Einstein's General Relativity shows us that this would require an infinite amount of energy. No magnet, however powerful, could provide this. ***AGu***

DIY SCIENCE

SALT CRYSTAL DECORATIONS

We'd love to see pictures of your experiments. Send them to us on Facebook or Twitter (@sciencefocus) and we'll share our favourites!

WARNING
Make sure you have adult supervision when boiling water or handling the hot saucepan.

WHAT TO DO

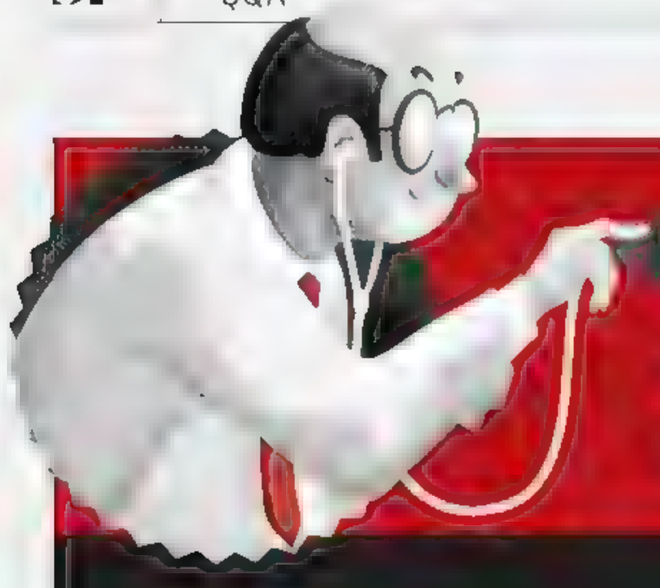
1. Cut the paper into stars, Christmas trees, holly leaves or other festive shapes. Punch a hole in the shape if you intend to hang it from a tree.
2. Place the paper shapes on the baking tray, spreading them out so they don't overlap. You can use sticky tack to hold the shapes in place.
3. Bring the water to the boil in a small saucepan, then turn down the heat so the water is gently simmering.
4. Add one tablespoon of salt to the water and stir vigorously until all the salt has dissolved.
5. Keep dissolving salt one tablespoon at a time (some of the final tablespoon may not dissolve).
6. Pour some of the hot salt solution into the tray – just enough to cover the paper shapes with a thin layer of liquid.
7. Leave the tray somewhere it won't be disturbed for two to three days, and wait as the salt crystals grow.
8. If the water hasn't fully evaporated by the time the paper shapes are covered with crystals, carefully remove the shapes and leave them to dry on a piece of kitchen towel.
9. Thread string through hole and hang from tree.

WHAT'S HAPPENING

Household table salt (sodium chloride) is made up of positively charged sodium atoms (ions) and negatively charged chlorine ions, strongly held together in a crystal structure by their electrostatic attraction.

Water dissolves salt because the water molecules enclose the individual sodium and chlorine ions in a sort of cage, which overcomes the strong forces between the ions. In hot water, the particles all move around faster and become more mixed up, which allows more of the ions to become surrounded by water molecules, so more of it is dissolved.

The salt solution you've made is 'supersaturated' – which means it has so much salt in it that the water can no longer dissolve it all. As the solution cools and evaporates, it's able to hold even less salt – so the sodium and chlorine ions are forced out of solution and reform into crystals, some of which stick to the paper. The cubic crystals form a neater pattern if the solution is allowed to evaporate slowly, otherwise impurities in the solution can become part of the crystals' structure, disrupting their appearance. ***AS***

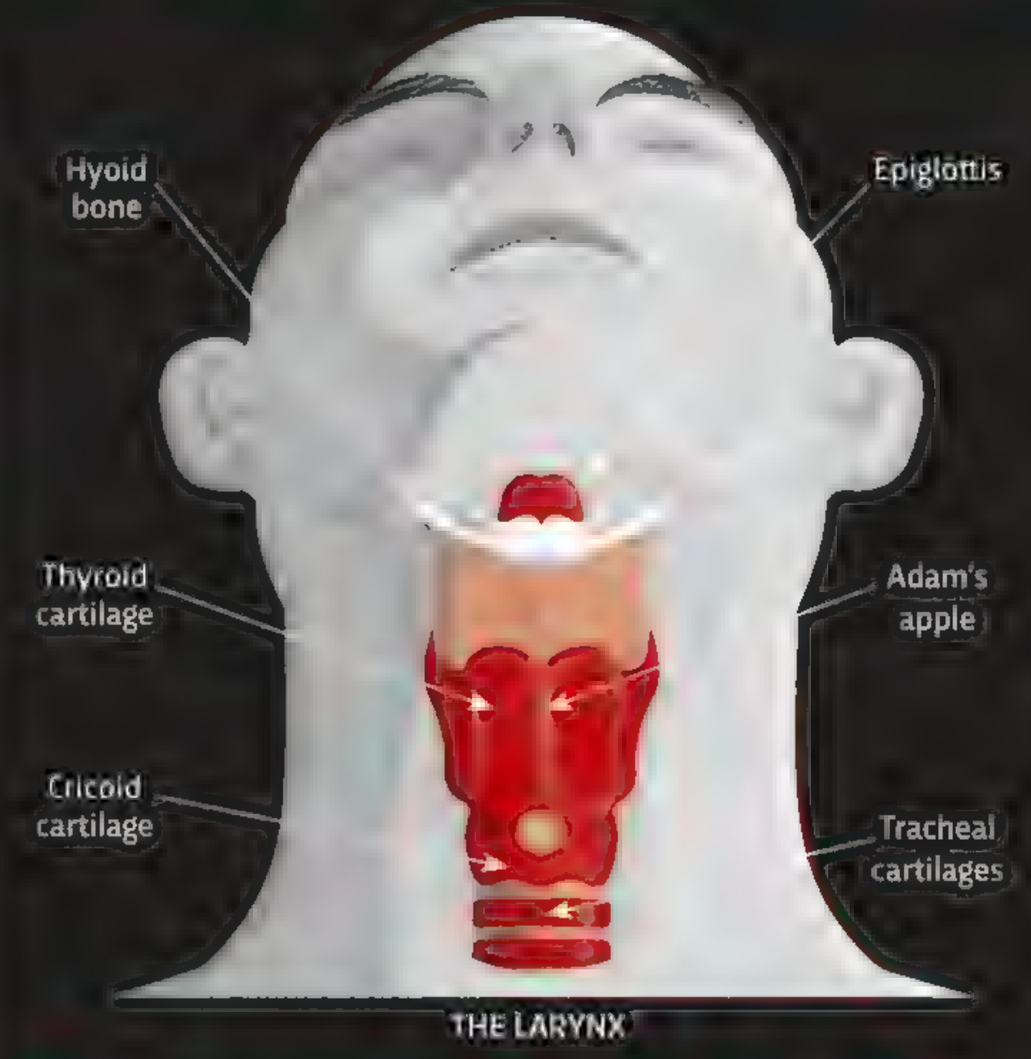


DEAR DOCTOR...

DELICATE ISSUES DEALT WITH BY *SCIENCE FOCUS* EXPERTS

EVERY CHRISTMAS, I SPEND AGES THINKING OF PRESENTS, BUT THEY GO DOWN LIKE A LEAD BALLOON. WHY AM I SO TERRIBLE AT READING PEOPLE?

You might be trying too hard. We often see gift-giving as a test of how well we know the person, as well as our inventiveness and thoughtfulness. But 2011 research at the Harvard and Stanford found that people prefer to receive items from an online 'wish list' rather than getting a surprise, no matter how well intended. If you do want to think up your own presents, though, you could see gift-giving as a chance to share something about yourself. A 2015 study by psychologists in Canada and the US found that people felt a greater sense of closeness to someone who gave them a gift that said something about the giver's passions and interests, rather than the recipient's. One final thought: consider gifting an experience, such as a meal out or a balloon ride. A 2016 study in the *Journal Of Consumer Research* found that experiential gifts boost relations between giver and receiver more than material gifts (even when the experience isn't shared), and that this is due to the intensity of emotion that's felt during the gifted experience. ***LV***



THE LARYNX

I'M EMBARRASSED BY MY MASSIVE ADAM'S APPLE. CAN I DO ANYTHING ABOUT IT?

The Adam's apple is the notch at the top of the thyroid cartilage – one of nine cartilages that form the protective skeleton around the voice box (larynx). Men and women both have Adam's apples, but they tend to be larger and more visible in men because their thyroid cartilage grows more during puberty, enlarging the larynx and deepening the voice. The Adam's apple itself serves no particular purpose and can be reduced in size without changing the nature of the voice (in gender reassignment surgery, for example). ***HG***

IF SOMEONE ATE THEIR CHRISTMAS CHOCS TOO QUICKLY AND SWALLOWED SOME FOIL, WOULD THEY DIE? ASKING FOR A FRIEND.

The aluminium foil that's used to wrap chocolates will react with the hydrochloric acid in the stomach to some extent, but this isn't a serious cause for concern. Even if all the aluminium in a typical chocolate wrapper spent long enough in the stomach to completely react, it would still give you less than 2 per cent of the acute toxic dose of aluminium chloride. That's the worst-case scenario, though – scrunched balls of foil typically pass all the way through, largely undigested. ***LV***

ROBERT SEDGWICK, VIA TWITTER

IS THERE A MAXIMUM AMOUNT OF LIQUID A HUMAN CAN DRINK IN A DAY?

Your kidneys can remove 0.8 to 1 litres of water per hour, so theoretically you could drink 20 litres of water in a day. This assumes that you drink at an even pace, though. There are cases of fatal water intoxication where the victim has drunk seven litres in three hours or less. This sudden influx of water increases the amount of water in the blood, which in turn reduces the concentration of minerals in the blood known as 'electrolytes' (these include sodium, potassium and magnesium). The concentration of minerals becomes less than that inside the body's cells, and so water moves into the cells by osmosis, to balance the concentration, and the cells swell. In the brain, this swelling is particularly dangerous because the brain is enclosed within the skull, and it cannot expand. So the increased pressure can result in brain damage and even death. ***LV***

DUNCAN WHERRETT, BERWICK-UPON-TWEED

HOW DO SMALL AND ISOLATED TRIBES COPE WITH INBREEDING?

Inbreeding – the production of offspring from parents who are genetically close together – can lead to health problems. This is because there's an increased risk of the offspring having a 'recessive' genetic disease. Recessive diseases require two copies of a harmful gene to develop – one from each parent – and if the genomes of the parents are similar, there's a stronger chance that they'll both carry it. However, these harmful genes are generally rare, and it takes multiple generations of inbreeding for the risks to rise significantly. Even small Amazonian tribes have several hundred members, and tribal customs that encourage people to choose marriage partners who are not closely related are enough to keep the genes sufficiently well-mixed. Inbreeding is one of the factors that affects the success of a tribe, but land and food availability, and conflicts with Westerners and other tribes, are all bigger threats Inbreeding only becomes a serious problem when the population drops below 50 or so. ***LV***

SALLY DUFFY, BRIGHTON

WHAT WOULD HAPPEN IF THE EARTH BECAME TIDALLY LOCKED TO THE SUN?

If the Earth somehow became tidally locked – in which one hemisphere of the Earth is perpetually facing the Sun while the other remains shrouded in darkness – it would be bad news for life. There would be no seasons, and temperatures on the Sun-facing side would get hot enough to boil water. Meanwhile, the dark side would become frigid, with the only source of heat being the ocean circulation and winds from the sunny side. The huge difference in temperatures between the two hemispheres would likely create extremely violent winds and copious thunderstorms. Such a hugely unstable climate would probably mean that all but the most resilient life forms would have to cling to survival along the strip of land between the day and night hemispheres. ***AGu***

OLD WIVES' TALES...

BEER BEFORE WINE AND YOU'LL FEEL FINE

According to this saying, the order that you consume your alcoholic drinks matters (the complete phrase is: 'beer before wine and you'll feel fine; wine before beer and you'll feel queer'). But every hangover has the same culprit: alcohol. Alcohol is thought to cause hangovers in two main ways. First, it diverts water from your bloodstream to your bladder. Over the course of a night out, you'll lose more fluid than you drink, often resulting in a dehydration headache the next day. Second, a chemical called acetaldehyde is one of the intermediate products of alcohol digestion in the liver. This is even more toxic than alcohol itself, so you feel rough until it has been metabolised into safer compounds.

The total amount of alcohol you drink will have a much bigger effect on how you feel than the specific order of drinks. A 2019 study at Cambridge University found that volunteers given two and a half pints of beer, followed by four large glasses of wine, reported just as bad a hangover as those who had the wine first and then the beer. If there's any truth to this saying, it may be that the parties where you start on wine are more likely to get out of hand – perhaps because you get drunk faster on the stronger booze and find it harder to keep track of how many you've had. ***LV***

GETTY IMAGES X2, A. AMY ILLUSTRATION: DAN BRIGHT

HELEN COLLINS, MANCHESTER

IS IT POSSIBLE TO BE TOO TIRED TO SLEEP?

It's perfectly possible to feel tired and at the same time have trouble dropping off. Certain life stresses and health problems can leave us feeling exhausted, but at the same time make it difficult to relax and get to sleep. Also, missing out on sleep can disrupt our natural rhythms, which can make us feel wide awake when we'd usually be sleeping. Finally, caregivers sometimes refer to their infants as being 'too tired to sleep'. This happens when the baby has been awake for longer than their little bodies can cope with, resulting in stress and difficulties settling. ***AGr***

18,000

The age, in years, of a preserved puppy found in the Siberian permafrost. Scientists have not yet been able to establish if it is a dog or a wolf, but will be studying its DNA to find out if it is an evolutionary link between dogs and wolves

NATURE'S WEIRDEST CREATURES...

THE COCONUT CRAB

Like tiny acorns turning into giant oaks, the coconut crab – the world's largest land-living arthropod – has a humble start to life.

It begins as microscopic larvae, drifting through the tropical Indian and Pacific Oceans in vast swarms of plankton for several weeks, before sinking to the seafloor. There, it finds a temporary shell to wear, before heading towards dry land (Christmas Island in the Indian Ocean is a favourite haunt). The crabs reach sexual maturity after five years, but it takes 40 to 60 years for them to reach their maximum size, weighing more than four kilograms and measuring a gargantuan one metre across.

To survive its terrestrial life, the coconut crab has evolved a lung-like organ which allows it to pull oxygen directly from the air. It's an adept climber, and its claws are highly muscled, allowing it to crack open the coconuts on which it occasionally feeds. It's even able to wiggle its antennae like an insect in order to track windborne smells. In fact, the adult coconut crab is so well adapted for life on land that it can drown if trapped underwater.

Rotting fruits are a favourite food source for the coconut crab, but it also consumes carrion and can even take on large prey, including rats and turtle hatchlings. Terrifyingly, larger individuals have been witnessed raiding bins. ***JH***

TIM HARRISON, VIA EMAIL

DO THE BENEFITS OF EXERCISE WEAR OFF AS YOUR BODY GETS USED TO IT?

The benefits definitely diminish, but not because you get used to the exercise – it's because your fitness level gets closer to the optimal level. Your strength and endurance can't increase indefinitely, for a variety of biological limits. Your muscles have a maximum size that is strongly affected by genetics, and the same is true of the strength of your tendons and the oxygen-carrying capacity of your lungs. Sustained exercise at high levels (such as running more than 48 kilometres per week) has actually been shown to have a negative impact on your long-term health, causing permanent damage to the muscle fibres and nerves in the heart. A 2013 study of over 52,000 cross-country skiers found that those who had completed the most races had the highest chance of suffering heart rhythm problems. ***LV***

GETTY IMAGES X3 SHUTTERSTOCK NATUREPL.COM ILLUSTRATIONS DAN BRIGHT

CROWDSCIENCE

We've teamed up with the folks behind BBC World Service's *CrowdScience* to answer your questions on one topic. You can tune into *CrowdScience* every Friday evening on BBC World Service, or catch up online at **www.bbcworldservice.com/crowdscience**

COULD HUMANS HIBERNATE?

WHAT EXACTLY IS HIBERNATION?

As temperatures drop and food becomes scarcer during the winter months, some animals have evolved to skip the cold season altogether and enter a state of inactivity. During this time, body temperature, metabolism and breathing rate all drop, allowing animals to conserve energy as they use up the body fat they've stored in advance. Well-known hibernators include hedgehogs, dormice, bears and bats, with the latter slowing their breathing down to as little as five breaths per minute. Even some amphibians are able to enter a hibernation-like state. The wood frog, for instance, freezes solid over winter – its heart stopping entirely – before it thaws out and hops off again in spring.

COULD HUMANS DO IT?

In 1999, a Swedish woman called Anna Bågenholm became trapped in an ice-covered river for 80 minutes following a skiing accident. She had no pulse when she was pulled out, but, remarkably, as doctors warmed her blood at the hospital, her heart restarted. Today, she is back to almost full health. Anna had entered a state of cold-induced torpor, similar to what animals experience during hibernation. For human hibernation, scientists would need to find a way to replicate this process safely, for long periods of time. One potential issue is that hibernation appears to lead to memory loss in some animals, so the effects of hibernation on cognitive processes needs to be explored in more depth. Turn to p13 for a news story about induced hypothermia.

WHY WOULD WE WANT TO HIBERNATE?

If humans are ever to set up home outside the Solar System, we'll need to overcome the vast distances between the stars. The closest star system to Earth, for example – Alpha Centauri – would take over four years to reach, and that's travelling at the speed of light. In reality, an interstellar journey is likely to take decades, centuries or even millennia, with generations coming and going in a single journey. Being able to hibernate for long periods could help to save on food and space, as well as reducing boredom. It could also lower the risks of cancer associated with radiation exposure. Hibernation reduces metabolism and cell division, in turn reducing the DNA-degrading impact of radiation on the body.

Rory Galloway is the producer of *Could humans hibernate during interstellar flight?* – an episode of *CrowdScience* that can be streamed at **bbcworldservice.com/crowdscience**

WHAT CONNECTS CHRISTMAS TREES AND THE BANK OF ENGLAND?

1. Christmas trees were introduced to Britain by King George III's wife, Queen Charlotte, in 1800, but they didn't become fashionable until Queen Victoria's reign. Today, 60 million are grown in Europe each year

2. Electric fairy lights became a popular way to decorate Christmas trees from around the 1930s onwards. Before then, small candles were often used – a health and safety nightmare!

3. *The Chemical History Of A Candle* was the title of Michael Faraday's 1848 Royal Institution Christmas Lectures. Faraday initiated these lectures in 1825, and delivered 19 of them in total – more than anyone else

4. Faraday's immense contributions to the study of electromagnetism and electrochemistry led to his commemoration by the Bank of England, who pictured him on their £20 note issued between 1991 and 2000

PETER LONG, SLOUGH

WHY IS LONG HAIR OFTEN CONSIDERED FEMININE?

It's not too hard to find cultural exceptions; in early to mid-18th Century France, for example, men's hair was typically longer than women's. But it remains the case that through history and across the world, long hair has tended to be seen as a feminine asset. One explanation comes from evolutionary psychology. It states that men are generally attracted to women with a youthful and healthy appearance (indicative of greater fertility), whereas women are more attentive to signs of physical strength and 'formidability'. Hair length might have emerged in this context as a visual signal of a woman's fecundity. Certainly, hair tends to grow faster and thicker when people are younger and healthier. Consistent with this account, research including a 2017 study by US psychologists has found that men, on average, perceive women with longer hair as more attractive, healthy and youthful. Of course, even if this evolutionary account is true, cultural forces and individual differences also play a strong role in whether we think of long hair as 'feminine'. ***CJ***

ROB BANINO, BRISTOL

DO I REALLY NEED TO WASH VEG IF I'M GOING TO BE COOKING IT?

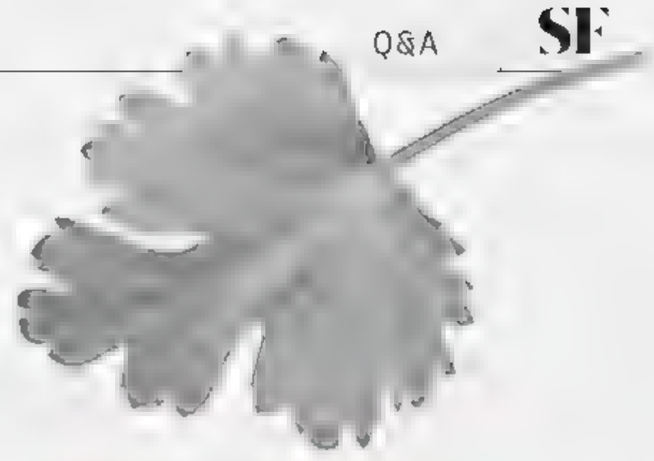
Afraid so – although boiling or steaming your veg will kill off any bacteria, there's still the problem of pesticides, which can wash off the vegetables and hang around in the water while cooking. Thorough washing and drying with clean kitchen paper will help remove any pesticide traces. It's also recommended to remove traces of soil before you start preparing the veg, as this can contain a host of bacteria, including *E. coli*, and contaminate work surfaces. ***ED***

GETTY IMAGES X6 ALAMY ILLUSTRATIONS DAN BRIGHT

JAMES REED, AGE 14, TAUNTON

MY MUM ALWAYS BEATS ME AT *MONOPOLY* AND INSISTS ON DOING AN EMBARRASSING 'VICTORY TWERK'. HOW CAN I WIN?

Don't despair. *Monopoly* does involve a large degree of luck, but there's still scope for making the most of what fortune comes your way. Computer analysis by US *Monopoly* expert Tom Friddell has shown that Trafalgar Square is the most landed-on property, and thus worth bagging as soon as possible. The most landed-on colours are red and orange – partly because they often catch people coming out of jail – so these are always good properties to own. But don't get too picky or focus on saving your money for later. Friddell's analysis shows it's better to own squares as soon as you can. And when you own a colour group, put three houses on all properties before buying any more. Rushing to get a hotel on one property will lower your chances of recuperating your building costs. If this all sounds like too much effort, then just remember this: if your mum has bagged most of the red and orange squares, there's little chance of you winning, so just make your excuses and quit. ***RM***



HARRY CLARKE, VIA EMAIL

WHY DOES CORIANDER TASTE LIKE SOAP TO SOME PEOPLE?

As many as one in five people says that coriander has a soapy taste. This is likely to be due to a super-sensitivity to chemicals called aldehydes, which are present in coriander and are also used to perfume soaps and detergents. In 2012, researchers in California analysed the DNA of over 14,000 people, identifying two genetic variants associated with the soapy taste, the most common of which is a gene coding for an odour receptor tailored to sniff out aldehydes. ***ED***

QUESTION OF THE MONTH

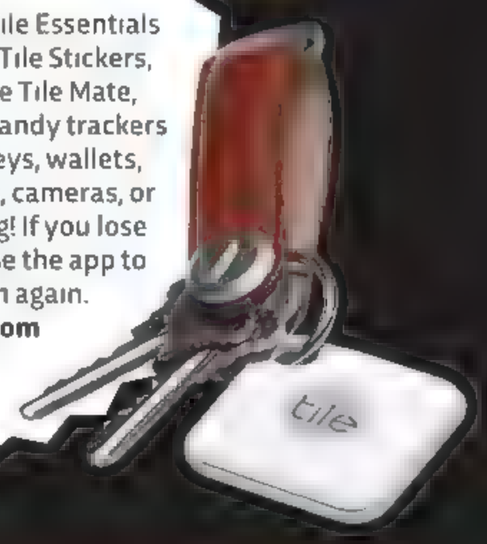
MIKE AND ERIKA, CAMBRIDGE

ARE CAMOUFLAGED ANIMALS AWARE THAT THEY CAN ONLY HIDE IN CERTAIN ENVIRONMENTS?

Many animals will choose where they stand in order to maximise their camouflage. For example, the common baron caterpillar (pictured) has a prominent stripe along its length that looks exactly like the central rib of the mango leaves on which it feeds. Natural selection has clearly favoured caterpillars that line themselves up with the leaf rib so they blend in better, but it seems unlikely that individual caterpillars know why they do this – it's simply a behaviour that's programmed into their genes. This is true of all invertebrates and most fish, reptiles and amphibians, but some more intelligent species – particularly among birds and mammals – show some awareness. Japanese quail, for instance, are ground-nesting birds who lay eggs with speckled patterns that vary widely from one bird to another. A 2013 study at Abertay University in Dundee found that quail who laid darker eggs were more likely to select darker nesting sites, and vice versa. ***LV***

WINNER

Mike and Erika win a Tile Essentials Pack, containing two Tile Stickers, one Tile Slim and one Tile Mate, worth £64.99. These handy trackers can be attached to keys, wallets, phones, glasses cases, cameras, or pretty much anything! If you lose your stuff, you can use the app to track them down again.
thetileapp.com



EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM** OR TWEET US **@SCIENCEFOCUSQA**

RADAR

WHAT'S LIGHTING UP OUR FESTIVE ANTENNA THIS MONTH

WATCH

HERE'S OUR PICK OF FREE THINGS TO DO OVER THE FESTIVE PERIOD CHECK *RADIO TIMES* FOR PROGRAMME SCHEDULES

THE LAST IGLOO

24 December, BBC Four

The igloo is thought to be one of the earliest human dwellings, but with the Arctic warming at an alarming rate, and snow and ice disappearing, they too may soon be lost. This stunning film follows Julius, an Inuit hunter in Greenland, who has left his settlement to hunt. He builds a shelter out in the wilderness with the precision and craft of the generations before him, but could he be one of the last?

EARTH'S TROPICAL ISLANDS

Episode one: due to air between Christmas Day and New Year's Day, BBC Two

For fans of *Seven Worlds, One Planet*, this series from BBC Two will showcase the wonder and beauty of three of the most remote islands on Earth: Madagascar, Borneo and Hawaii. These are fragile places, from which we can gauge the health of our planet. Harbouring over 60,000 species of animals and plants, Borneo is more diverse than any other island. Madagascar, the oldest island on Earth, is home to animals found nowhere else on the planet. And only the toughest can survive on remote Hawaii.

SECRETS OF SKIN

Begins Christmas week, BBC Four

A vertebrate's skin helps them communicate, sense the world around them and protects from outside elements. In this six-part series, Prof Ben Garrod argues that the largest organ in an animal's body has allowed vertebrates to dominate on planet Earth. In episode one, Ben discovers how the blueprint for skin is extraordinarily versatile.

VISIT

MEDICINE: THE WELLCOME GALLERIES

Science Museum, London

See Fleming's penicillin mould and the world's first MRI scanner, then take control of an infectious disease in the Science Museum's new permanent galleries. With 3,000 medical objects on show, *Medicine. The Wellcome Galleries* reveals our relationship with health and medicine over the last 500 years. Through stories from patients and practitioners, commissioned artworks and immersive digital experiences, visitors are urged to consider their connection to health, their body and mortality. Free entry

bit.ly/medicine-wellcome-galleries

THE FORGOTTEN SHOWMAN

Science and Media Museum, Bradford

Remembering Robert Paul, engineer and hero of British cinema, 150 years after his birth. Paul's story begins in the 1890s, when he designed the instruments and equipment that would lead to the creation of the first film studio in Britain. Visitors to the museum can see his original innovations, including the 35mm camera Paul used to film the 1897 Diamond Jubilee Procession of Queen Victoria. Free entry

Until 29 March

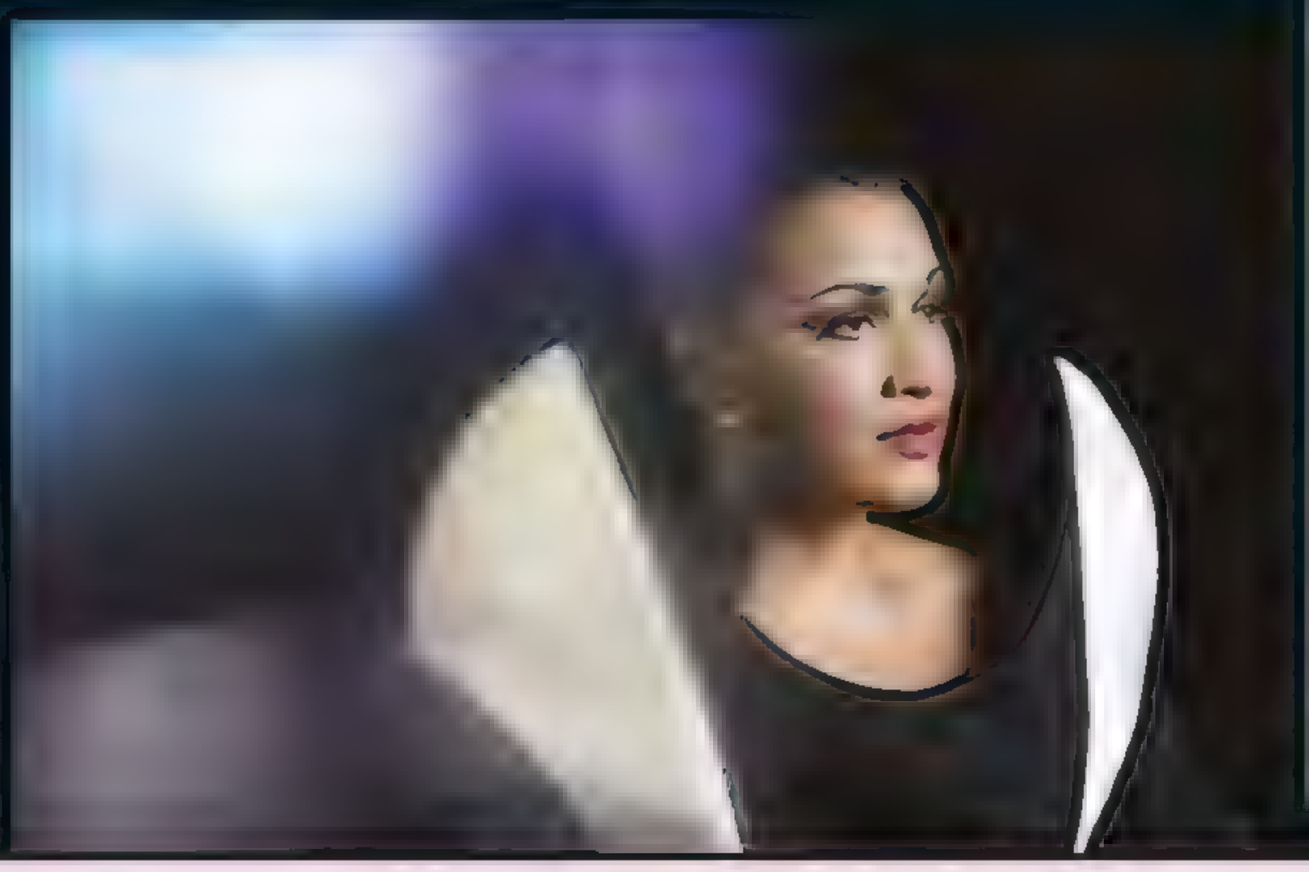
bit.ly/forgotten-showman

LISTEN

SWOOSHES, SEABOARDS, SYNTHS AND SPAWN

26 December, 11:30am, BBC Radio 4

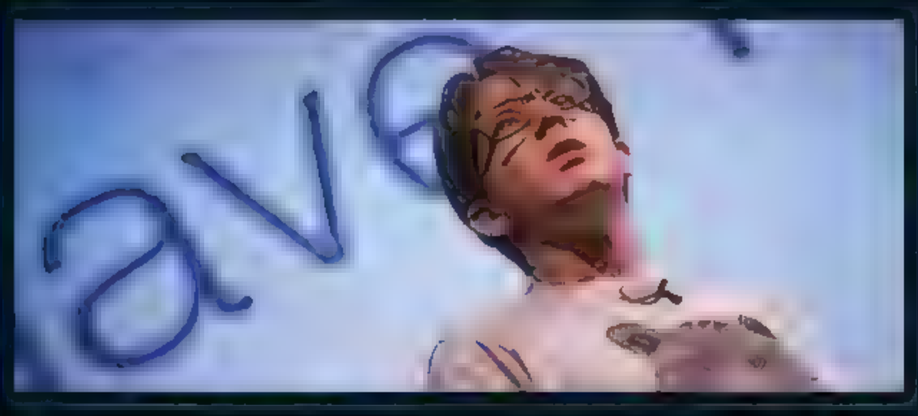
What is the future of music, and how will technology and artificial intelligence affect the next chart-topping hit? Singer, tech enthusiast and multi-instrumentalist Bishi finds out how recent innovations like artificial musical brains and tactile synthesisers are at the forefront of music composition.



JAMES VEITCH'S CONTRACTUAL OBLIGATION

7 [illegible] December, 10:30am, BBC Radio 4

Comedian James Veitch has agreed to create more podcasts for BBC Radio 4, but he's running out of ideas. Can science help? Mindfulness expert Dr Sam Harris is one of the guests in these new episodes of the programme.



WORLD WISE WEB

From 14 January

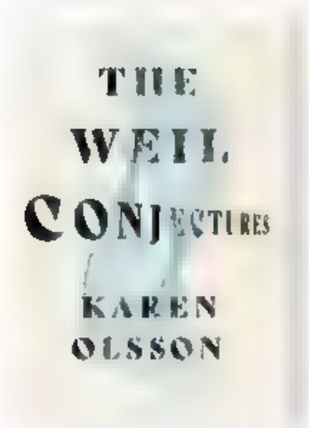
Hosted by 17-year-old Anna Zanelli, this new podcast and radio series from BBC World Service brings techy teens and STEM experts together to discuss today's technological world. Each episode focuses on a recent innovation, from the Apple iPod to Google Search, delivery drones and prosthetic limbs.

RECOMMENDED

2019'S ESSENTIAL READS

OUR FAVOURITE BOOKS FROM THE LAST 12 MONTHS...

AMY BARRETT, EDITORIAL ASSISTANT



THE WEIL CONJECTURES

KAREN OLSSON
£14.99, BLOOMSBURY

André and Simone Weil were brother and sister. One a renowned mathematician known for contributions to algebraic geometry and number theory, the other a famous philosopher and political activist. Maths and philosophy become entangled in this fascinating memoir of the two 20th-Century figures

SOMETHING DEEPLY HIDDEN

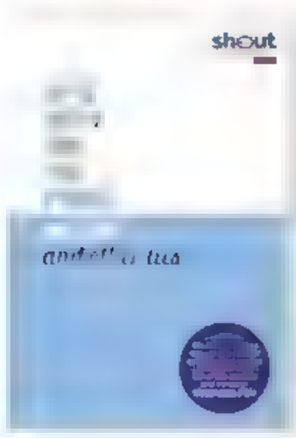
SEAN CARROLL
£20, ONEWORLD

From physicist Sean Carroll comes a history of quantum discoveries, and a guide to a subject that has baffled and blinded with its potential. Tackling huge questions, myths and conundrums about our Universe is no easy task, but Carroll does so elegantly

STILLICIDE

CYNAN JONES
£12, GRANTA

Set in the near future, this fiction book tells the story of a Britain caught between floods and droughts, where water is a commodity to be fought for. Hear the narration of the story on the BBC Radio 4 podcast of the same name



IT'S NOT OK TO FEEL BLUE AND OTHER LIES

CURATED BY SCARLETT CURTIS
£14.99, PENGUIN

Singer Sam Smith and actress Emilia Clarke are two of over 70 contributors to this collection of essays, stories and poems about their own mental health. One to pass between friends, family and colleagues, to generate conversations around a needlessly taboo subject

ANATOMICUM

JENNIFER PAXTON AND KATY WIEDEMANN
£25, WELLCOME

This beautiful book explores the human body from underneath the skin as if it were a journey through a museum. Katy Wiedemann's delicately drawn diagrams accompany Jennifer Paxton's detailed anatomical information for a learning experience that is quite unlike any other.

SUPERHEAVY

KIT CHAPMAN
£16.99, BLOOMSBURY SIGMA

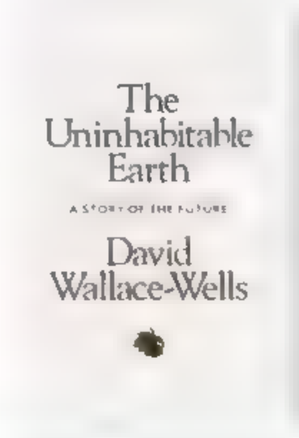
How do scientists make elements that don't naturally exist? In this engaging book, Kit Chapman opens our eyes to the way superheavy, unstable elements at the far reaches of the periodic table have changed our lives, and predicts what's next for nuclear science.

ON OUR PODCAST

SUPERIOR

ANGELA SAINI
£16.99, 4TH ESTATE

A timely look at the history of racism and racial bias within the scientific community. Perhaps most shocking is the sign of race science returning to modern conversations around genetics and political power



THE UNINHABITABLE EARTH

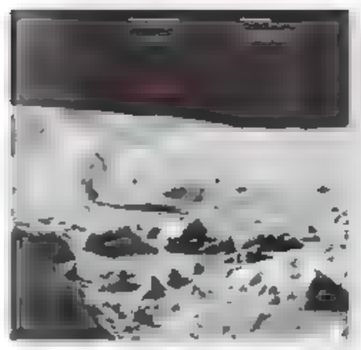
DAVID WALLACE-WELLS
£9.99, PENGUIN

What will continued climate change do to our planet? The future is much worse than we think, says David Wallace-Wells, who is deputy editor of *New York* magazine and a science writer. Sparking debate and conversation across the world, *The Uninhabitable Earth* is one of 2019's best books

THE NASA ARCHIVES: 60 YEARS IN SPACE

PIERS BIZONY, ANDREW CHAIKIN AND ROGER LAUNIUS
£100 TASCHEN

A stunning visual journey through the NASA archives, documenting six decades of space exploration. Essays discuss the past, present and future of the American space agency, and with over 400 images, illustrations and photographs, most not widely seen by the general public, this is a coffee table book that is a delight to pick up and peruse

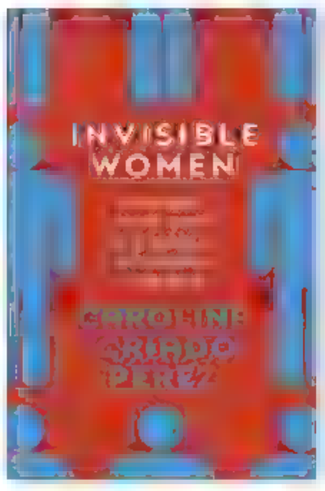


ON OUR PODCAST

INVISIBLE WOMEN

CAROLINE CRIADO PEREZ
£16.99, CHATTO & WINDUS

The winner of this year's Royal Society Science Book Prize reveals the shocking way that the world was designed with only one gender in mind. From female participants missing from research studies, to health apps allowing users to track copper intake but not periods, the holes in our knowledge of women – called the 'gender data gap' by Criado Perez – has led to a history of discrimination



CHRISTMAS CRACKERS

HERE ARE THREE OF THIS YEAR'S BEST PUZZLE BOOKS. TRY OUT A TASTER BETWEEN HELPINGS OF CHRISTMAS PUDDING...

For answers, visit bit.ly/SciFoCrackers

ONLY CONNECT: THE DIFFICULT SECOND QUIZ BOOK

JACK WALEY-COHEN AND DAVID MCGAUGHEY
£14.99, BBC BOOKS

The toughest quiz on television is now in your hands. Can you find the link between seemingly unconnected dates? Will you be stumped by a sequence of letters? It's time to find out

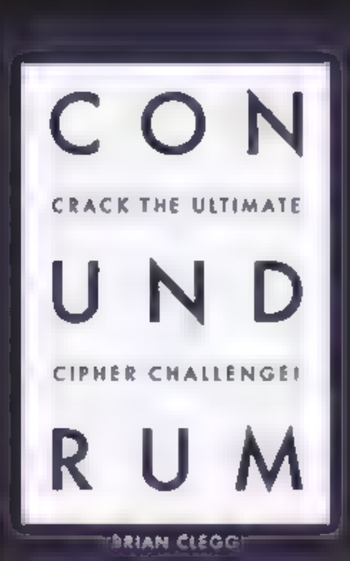
These moons have had their vowels removed. Can you work out what their names are?

P HB S

KT HM N

R P

S NM YN GM N



CONUNDRUM

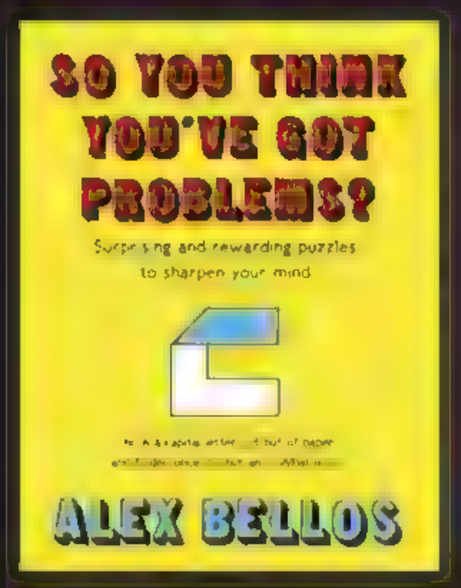
BRIAN CLEGG
£8.99, ICON BOOKS

For master codebreakers and less experienced puzzlers alike, Brian Clegg's book has something for everyone. Themed chapters including chemistry, maths and literature will help you dish out a puzzle along with some figgy pudding

Decipher this message to find a one-letter answer:

Einstein's Finest

nd²wm²cs²zp²br²pf²tj²mc²br²br²mc²
zp²wm²nd²iy²tj²xn²pf²iy²jz²mc²br²



SO YOU THINK YOU'VE GOT PROBLEMS?

ALEX BELLOS
£14.99, GUARDIAN FABER

The Guardian's puzzle columnist Alex Bellos presents problems along with a dash of history. You'll be trapped on an island, presented with cookies in a jar and challenged to catch a cat, all the while learning about why we love a brainteaser.

With two straight-line cuts, divide this vase into three pieces that can be reassembled to form a square.

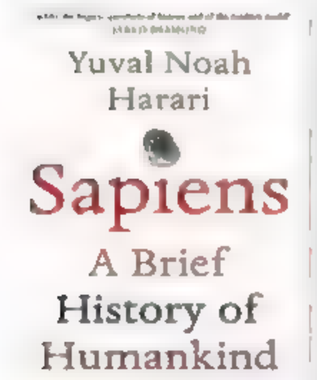
BEST OF THE DECADE...

WE LOOK BACK AT THE PAST 10 YEARS OF SCIENCE BOOKS, DOCUMENTARIES, FESTIVALS AND PODCASTS

BEST BOOKS BY ALICE O'KEEFFE

ALICE IS THE BOOKS EDITOR FOR *THE BOOKSELLER*. IN PRINT SINCE 1858, *THE BOOKSELLER* IS THE BOOK INDUSTRY'S TRUSTED SOURCE OF ALL THINGS BUSINESS AND PUBLISHING

This has been a wonderful decade for readers, as scientists, academics and medics published enthralling non-fiction for lay readers, and topped the bestseller charts in the process



SAPIENS: A BRIEF HISTORY OF HUMANKIND

YUVAL NOAH HARARI
£10.99, HARVILL SECKER, 2014

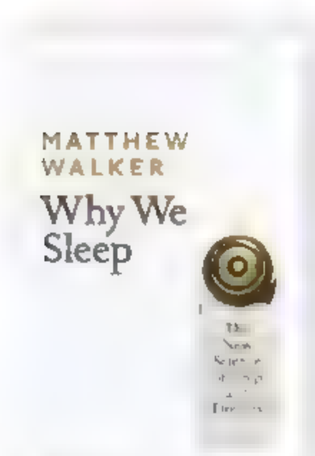
Covering 100,000 years in fewer than 500 pages, this fuses history, biology, anthropology, philosophy, psychology and more in a fascinating account of the rise of *Homo sapiens*

THIS IS GOING TO HURT: SECRET DIARIES OF A JUNIOR DOCTOR

ON OUR PODCAST

ADAM KAY
£8.99, PICADOR, 2017

The first in a slew of 'medical memoirs' about what it's really like working on the frontline of the NHS. It is jaw-dropping, hilarious and heart-breaking



WHY WE SLEEP: THE NEW SCIENCE OF SLEEP AND DREAMS

MATTHEW WALKER
£9.99, PENGUIN, 2017

A compelling and wide-ranging exploration of sleep, its crucial importance and what happens when we don't get enough.

ALAMY, BBC, JENNY DESMOND

BEST AUDIO BY ANNA BUCKLEY

ANNA IS A PRODUCER FOR BBC RADIO 4 AND HAS WORKED ON SERIES SUCH AS *THE LIFE SCIENTIFIC* AND *SEVEN AGES OF SCIENCE*

There are so many great radio shows and podcasts that have come out over the last 10 years, and I've been lucky to work on some fantastic programmes too. These are my favourites...

60-SECOND SCIENCE

This podcast from *Scientific American* values my time. Hurrah! It's the perfect antidote to podcasts that seem to ramble on as if we've all got all the time in the world. I don't, and so I love these self-contained, minute-long gems. With irresistible titles like *Ant colonies avoid traffic jams*, *Aversion to broccoli may be genetic* and *AI learns to talk back to bigots*, binge listening is almost inevitable.

CROWDSCIENCE

The best thing about BBC's *CrowdScience* is the questions. They are provided by listeners from all over the world and are a potent reminder of how many of our concerns are shared. Should I stop eating palm oil? How green are electric vehicles? Is maths real? The whole thing bounces along and you come away having learnt so much.

13 MINUTES TO THE MOON

This is the full story of the Eagle landing, told in forensic detail by the people who made the Apollo 11 mission possible. You hear the crackle as the communications fail, you panic when the fuel is running out. It's not until Neil Armstrong and Buzz Aldrin land on the Moon, after six glorious hours of listening, that you finally get to relax.

BEST EVENTS

BY JIM AL-KHALILI

AS A PHYSICIST AND SCIENCE COMMUNICATOR, JIM HAS GIVEN TALKS AT FESTIVALS ACROSS THE COUNTRY. HE ALSO PRESENTS *THE LIFE SCIENTIFIC* ON BBC RADIO 4 AND HAS WRITTEN SEVERAL BOOKS, INCLUDING HIS DEBUT NOVEL *SUNFALL*, PUBLISHED EARLIER THIS YEAR

Science festivals are springing up in cities and towns all over the UK, but to some extent we tend to be 'preaching to the choir'. However, when combined with arts and music, or within literary festivals, we can reach new audiences and I think that's more valuable.

BLUE DOT

Held at Jodrell Bank Observatory, this year I gave a talk on the main stage to around 5,000 people, which was an incredible buzz. I talked about time travel and Einstein's Relativity to an audience who were mainly there for the music, and it went down very well.

NORTHERN IRELAND SCIENCE FESTIVAL

This wonderful festival, which I attended in 2017, brought home how people in Northern Ireland are starved of access to science events. I don't think I've ever received such a warm reception from an audience!

CHELTENHAM SCIENCE FESTIVAL

I could have picked any one of the past 16 years' Cheltenham Science Festivals. Cheltenham has always been most science communicators' favourite, and the one that other festivals seek to emulate.

BEST TV BY HELEN CZERSKI

HELEN IS A PHYSICIST, OCEANOGRAPHER AND BBC SCIENCE PRESENTER, AND HAS WORKED ON PROGRAMMES SUCH AS *SUPER SENSES: THE SECRET POWER OF ANIMALS*, *DANGEROUS EARTH* AND *SOUND WAVES: THE SYMPHONY OF PHYSICS*

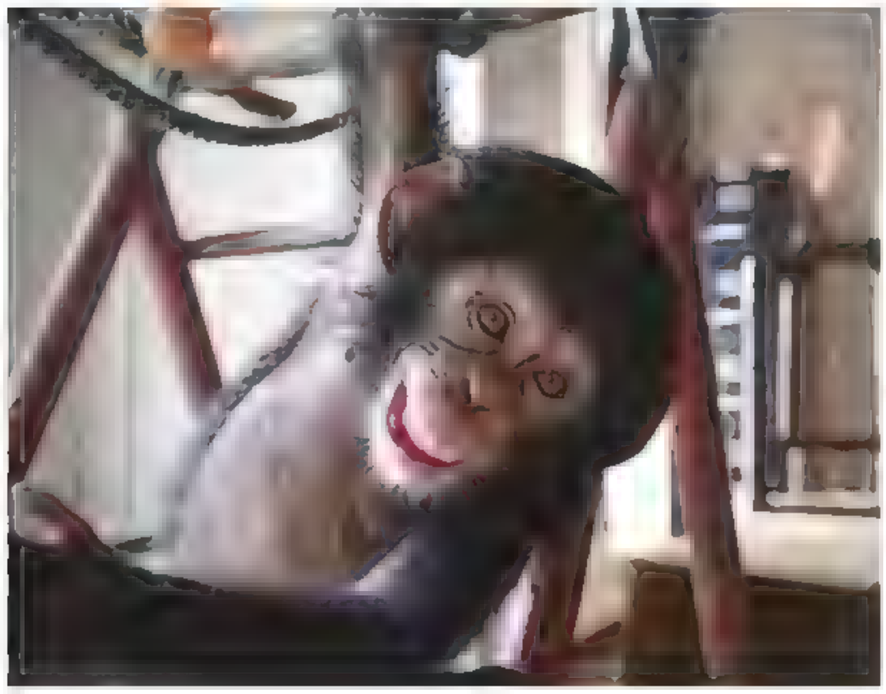
Documentaries are a great way of sharing in-depth science because they allow you (the presenter) to convey perspective in a visual way, as well as with words and physical demonstrations. When done well, it's incredibly creative. It's the perspective that matters, not individual facts, and the big blue-chip documentaries offered a fabulous opportunity to change how people see the world around them.

ALICE ROBERTS: THE ORIGINS OF US (2011)

Alice is one of the best science presenters this country has, and this series had it all: a great story, deep and relevant detail, and a fascinating range of locations and contributors

BANG GOES THE THEORY (2009-2014)

A fabulous and friendly series, like hanging out in your mate's shed while they investigate the world. The early programmes especially were great – so many ideas and so much enthusiasm!

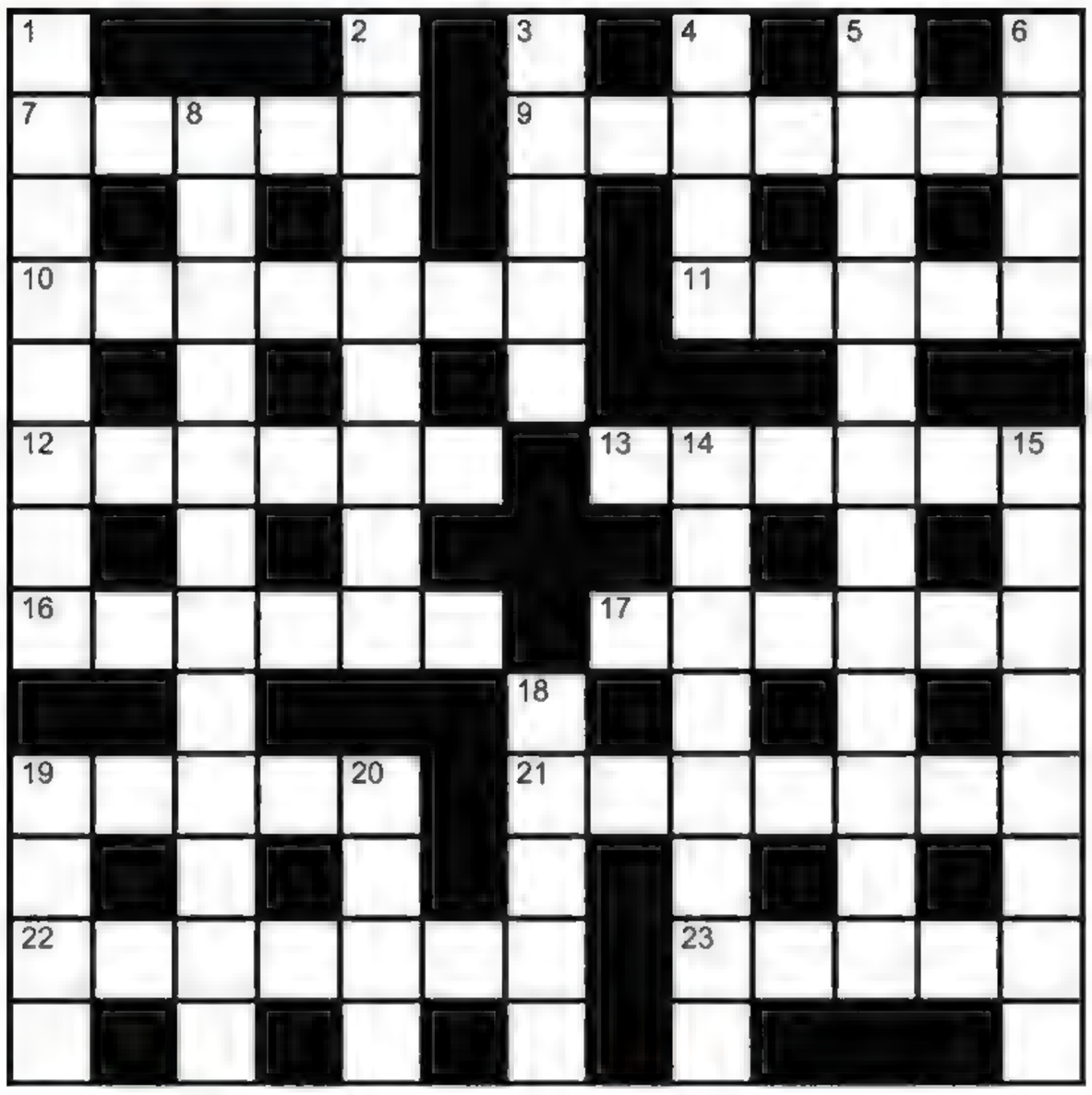


HORIZON: SHOULD WE CLOSE OUR ZOOS? (2016)

The public deserves more of this sort of programme. Liz Bonnin presented a real investigation of a difficult ethical topic, leading to big questions about how we do things in future.

CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

7 Right to boot out an automaton (5)
9 Space available for gold in performing area (7)
10 Flour transformed to a lunch, say (7)
11 Saw tonne being transported (5)
12 Ugly creature concealed a beautiful flower (6)
13 Finish in church city (6)
16 Darren's off on a mission (6)
17 Overcoat of unusual lustre (6)
19 Graduate returned equipment for crafty use of wax (5)
21 Extinct creature – it flies round a couple of Frenchmen (7)
22 Sport surrounding a secure area (7)
23 Relaxed at home, making material (5)

DOWN

1 Designed to score with English preservative (8)
2 A Scot went round, at that time a capitalist (8)
3 Part of hand holding second song (5)
4 Potential difference in victory – lot has changed (4)
5 Swimmer finds weather feature upset tutor (7,5)
6 Plant found right inside marshy region (4)
8 Pigment improved a better canoe (4-8)
14 Harold quickly gets married – a respectful position (4-4)
15 World citizen, left out, going to ground (8)
18 New aim – leave as an adult insect (5)
19 Expert in the altogether (4)
20 Took risk, having a dagger (4)

GETTY IMAGES

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive

NEXT ISSUE

COMET INTERCEPTORS

Meet the scientists who are hoping to capture a space rock that's come all the way from another galaxy

PLUS

IS MINING THE MOON A GOOD IDEA?

METRIC MAN

Health tests put under the microscope.

ZERO EMISSIONS

How the Orkney Islands are planning to go carbon-neutral.

ON SALE 15 JAN

SF

JANUARY SALE

Try something new for 2020

Subscriptions from just £1 an issue. With over 30 magazines to choose from, why not try something new this year with our introductory offer

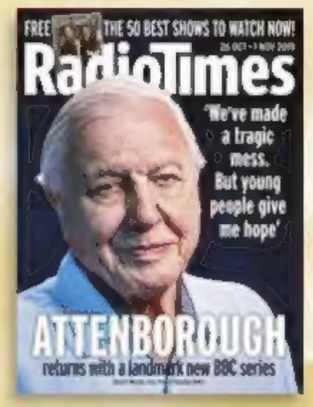
5 ISSUES FOR £5

5 ISSUES FOR £5

5 ISSUES FOR £5

5 ISSUES FOR £5

5 ISSUES FOR £5



6 ISSUES FOR £1

5 ISSUES FOR £5

5 ISSUES FOR £5

5 ISSUES FOR £5

5 ISSUES FOR £5

5 ISSUES FOR £5

3 ISSUES FOR £5

5 ISSUES FOR £5

5 ISSUES FOR £5

3 ISSUES FOR £5

3 ISSUES FOR £5

5 ISSUES FOR £5

5 ISSUES FOR £5

5 ISSUES FOR £5

4 ISSUES FOR £4

5 ISSUES FOR £5

GREAT REASONS TO SUBSCRIBE:

- Subscriptions starting from **just £1 an issue**
- Continue to make **great savings** after your trial period
- Enjoy easy and convenient **delivery direct to your door**
- **Never miss an issue** of your favourite magazine

2 EASY WAYS TO ORDER

Visit **buysubscriptions.com/January**

Call **0330 053 8660**†
quote code **JS20SP**

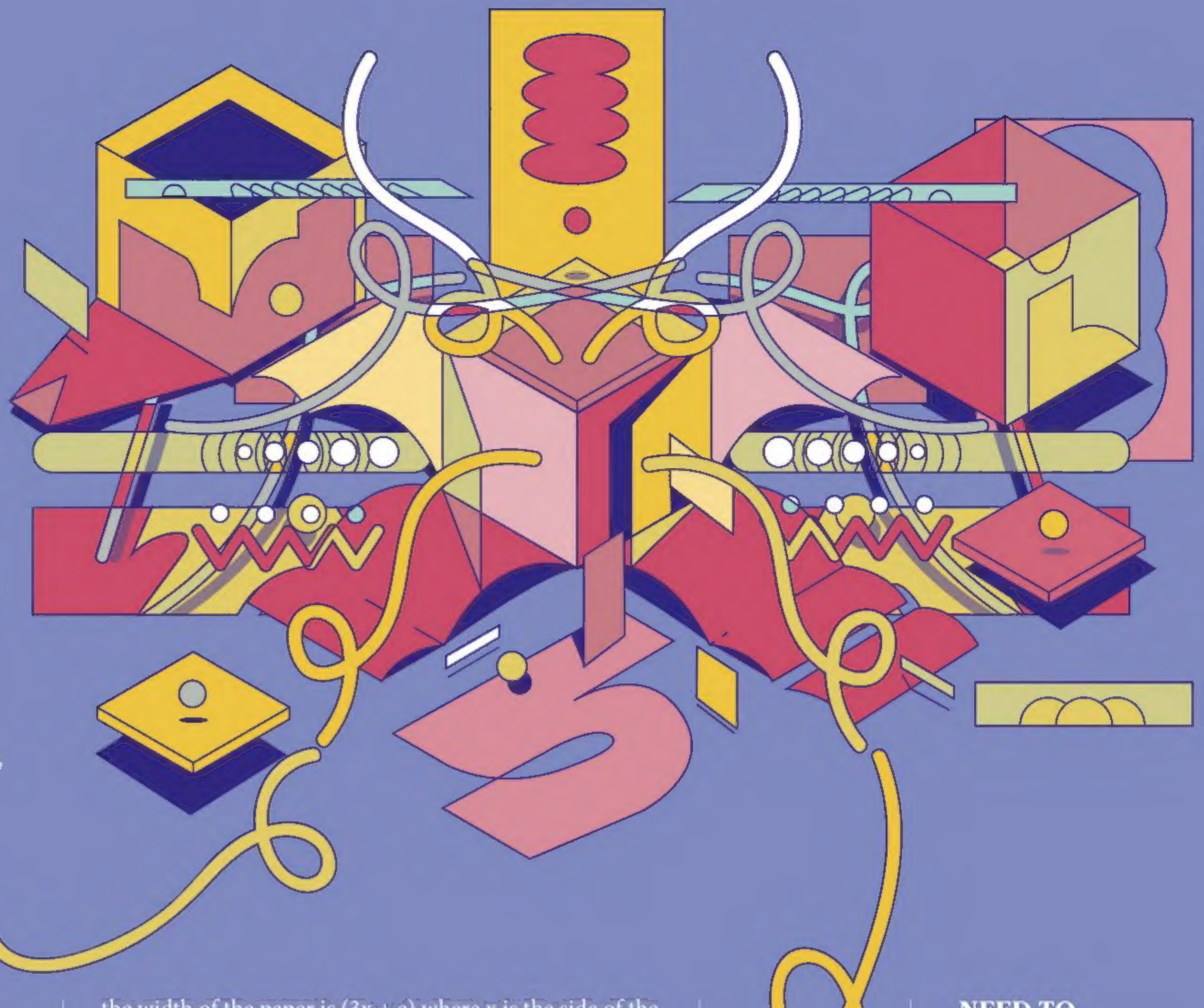
See more great magazines online...

*This offer closes on 12th February 2020 and is valid for UK delivery addresses and by direct debit only. The discounts shown are savings calculated as a percentage of the full shop price, excluding Radio Times and Match of the Day which are calculated as a percentage of the basic annual rate. For overseas rates visit www.buysubscriptions.com. Should the magazine ordered change in frequency, we will honour the number of issues and not the term of the subscription. You are free to cancel your subscription at any time – if you cancel within 2 weeks of receiving your penultimate issue you will pay no more than the trial rate, this is with the exception of Radio Times and Match of the Day, which you will need to cancel 3 weeks before the trial is due to end. Radio Times and Match of the Day are published weekly. The Basic Annual UK Subscription rate for Radio Times is £176. This price is for one year and includes the Christmas double issue and a contribution towards postage. The Basic Annual Rate for Match of the Day is £117 for one year. These rates are correct at time of printing. We run trial offers throughout the year to give our customers an opportunity to try a new title before committing to a long term subscription. These are introductory offers and we reserve the right to reject or cancel any application for a trial subscription offer if the customer has previously purchased a trial offer for the same magazine or any other magazine in the Immediate Media portfolio. For a full list of our titles visit buysubscriptions.com/portfolio. †UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) and are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). Outside of free call packages call charges from mobile phones will cost between 3p and 55p per minute. Lines are open Mon to Fri 8am – 8pm and Sat 9am – 1pm.

A SCIENTIST'S GUIDE TO LIFE

WRAPPING PRESENTS

THIS CHRISTMAS, DON'T BE DAUNTED BY THE PILE OF WRAPPING THAT AWAITS. POUR YOURSELF A SHERRY AND LEARN HOW TO WRAP PRESENTS USING GEOMETRY, WITH MATHEMATICIAN **KATIE STECKLES**



HOW DO MOST PEOPLE WRAP THEIR PRESENTS?

Most people learn to wrap a present by folding a piece of paper around an object, adding a bit of tape and then tucking in the ends. That's fine, but if you use maths you can make things more efficient and beautiful.

CAN A MATHS GCSE HELP ME TO WRAP PRESENTS BETTER?

It can help, but it's not essential. This is basic geometry. It's to do with size and shape of the object you're wrapping. Some shapes are easier to wrap. Others are more difficult.

WHAT'S THE BEST WAY TO WRAP A BOX OF AFTER EIGHTS?

That's a square prism – it's a square if you look at one end. Let's say the side of the square is x and the length of the box is L. Imagine wrapping a piece of paper around the sides of the square. The width of that paper needs to be 4x plus a bit extra for the overlap. We call this extra bit 'e'. So the width is $4x + e$. The length of the paper needs to be $(L + x)$. This means there is just enough paper at the ends to be folded neatly to make a cross shape.

WHAT ABOUT A TOBLERONE?

Ah, the equilateral triangular prism! (Other triangular chocolate bars are available – Editor.) This time the width of the paper is $(3x + e)$ where x is the side of the triangle. The length of the paper is $(L + 2h)$ where L is the length of the Toblerone and h is the height of the triangle measured from the base to the apex. This means that when you wrap the paper around and fold the ends in, you end up with a perfect triangle shape at each end… which is just incredibly enjoyable!

HOW SHOULD I WRAP A BOTTLE?

If d is the diameter of the base of the bottle, then the width of paper you need is $(\pi d + e)$. We know this because the circumference of a circle is πd. It's the thing that people learn in school and then immediately forget. The length should be at least $(L + d)$ so you can tape it shut at the bottom and tie a ribbon around the top, like a Christmas cracker.

WHAT'S YOUR FAVOURITE PAPER?

Something with an unusual pattern. It's been proven that there are only 17 different types of symmetrical pattern for wrapping paper or wallpaper. Some types of symmetry are more common than others – for example, surprisingly few wrapping paper patterns have reflection or rotation symmetry. I like those ones the best, but they're not easy to find in the shops!

HOW TO WRAP A JUMPER?

If you're wrapping something squidgy like a jumper or a pack of sweets, you can move the paper around so that you match up any symmetrical patterns. This is very satisfying.

WHAT'S YOUR TOP TIP FOR CHRISTMAS WRAPPING?

Arrange your gifts in order of size, then wrap them in decreasing size order starting with the biggest ones first. If you do this, you'll be able to wrap the little gifts using the offcuts left over from wrapping the big ones. **SF**

KATIE STECKLES

Katie is a mathematician and maths communicator from Sheffield Hallam University. Watch her wrap gifts mathematically at ***bit.ly/maths-wrap***

Interviewed by Dr Helen Pilcher

NEED TO KNOW...

1

A bit of simple maths can help you neatly wrap your pressies.

2

Move the wrapping paper about on squashy presents so that patterns line up.

3

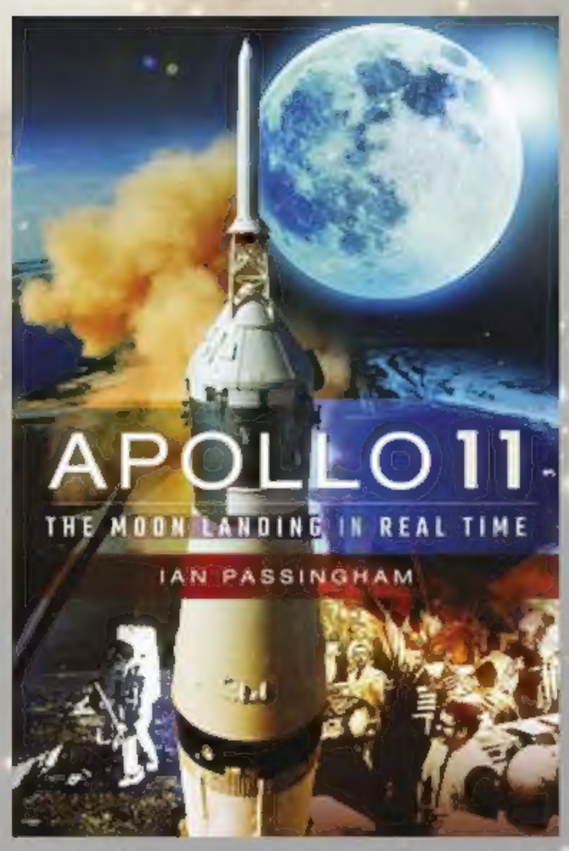
Wrap big presents first, so you can use offcuts of paper for the smallest gifts.

ILLUSTRATION: CARLOS ORTEGA

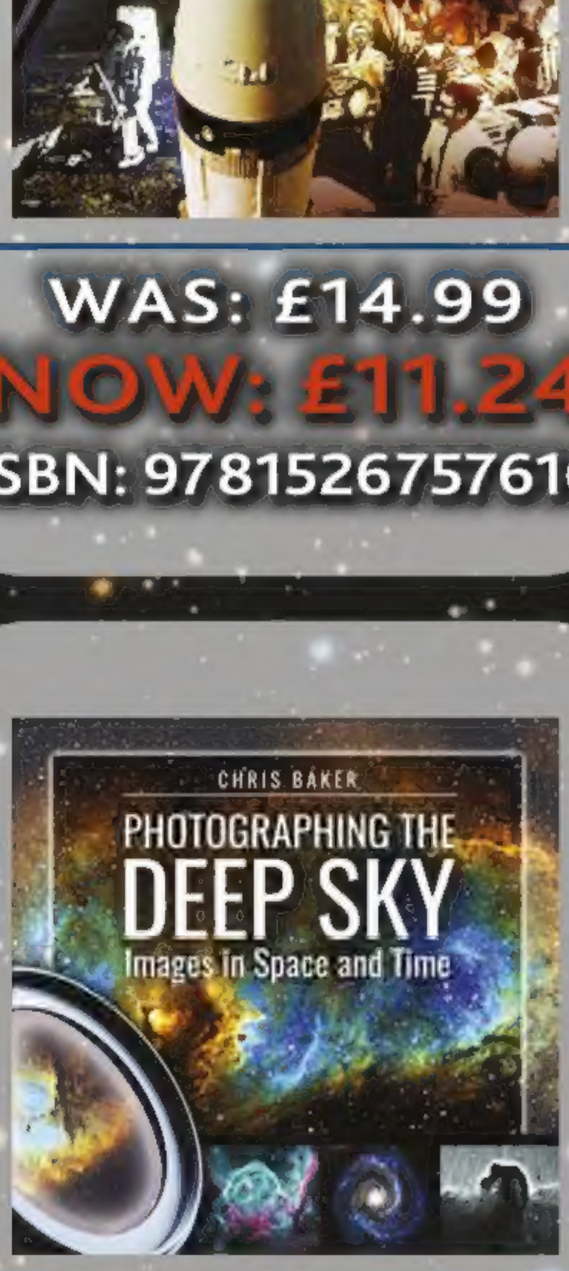
WHITE OWL BOOKS

an imprint of Pen & Sword Books

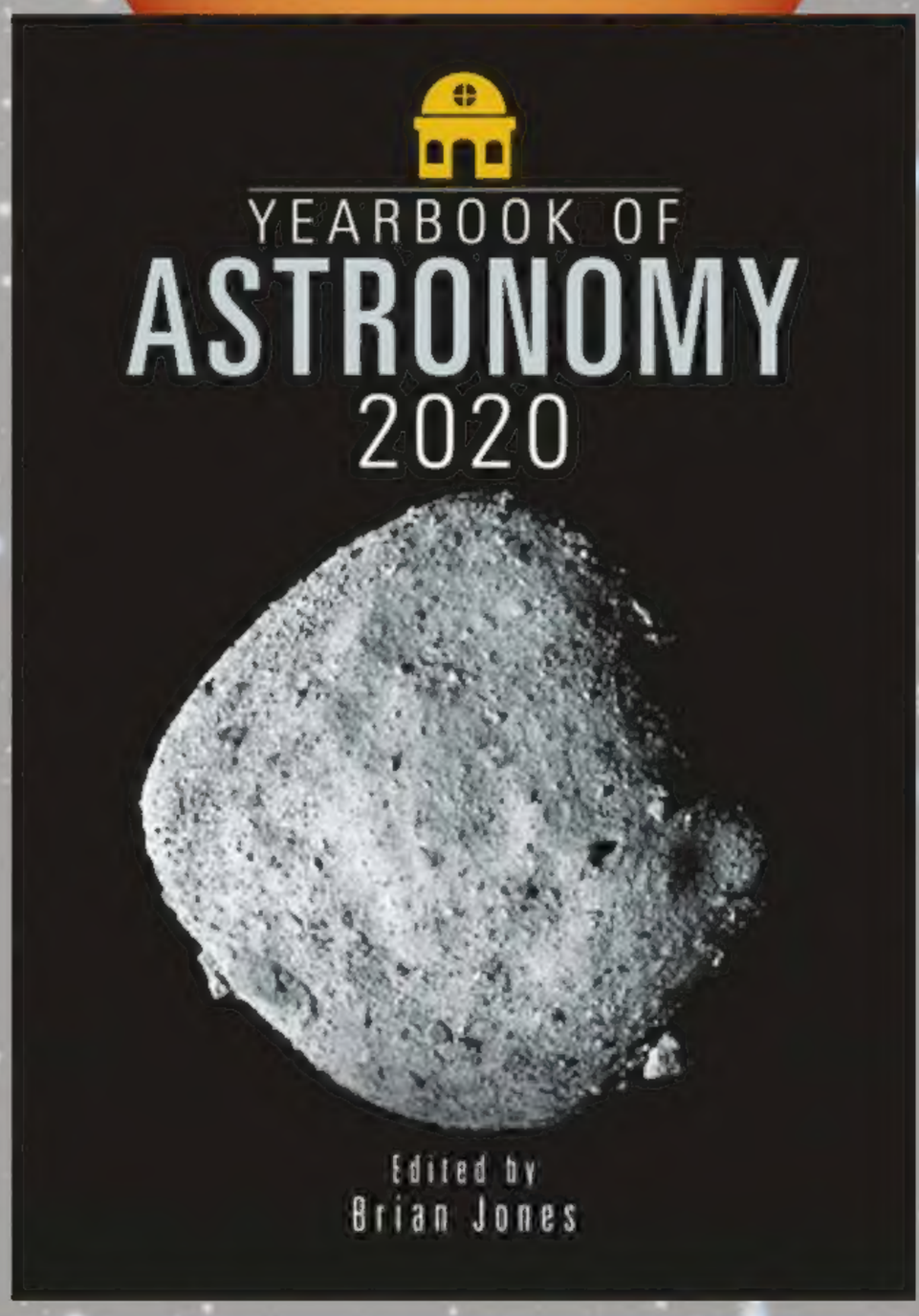
25% DISCOUNT



WAS: £14.99
NOW: £11.24
ISBN: 9781526757616



WAS: £25.00
NOW: £18.75
ISBN: 9781526715531



WAS: £16.99
NOW: £12.74
ISBN: 9781526753274

TO ORDER CALL AND QUOTE CODE **AAS97** TO RECEIVE YOUR 25% DISCOUNT:

01226 734222

OR ORDER ONLINE

www.whiteowlbooks.co.uk

Dan Clark Audio

NEW ÆON 2

"The Aeon is very possibly a headphone masterpiece."

electromod
the sound connection
www.electromod.co.uk